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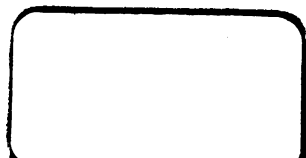
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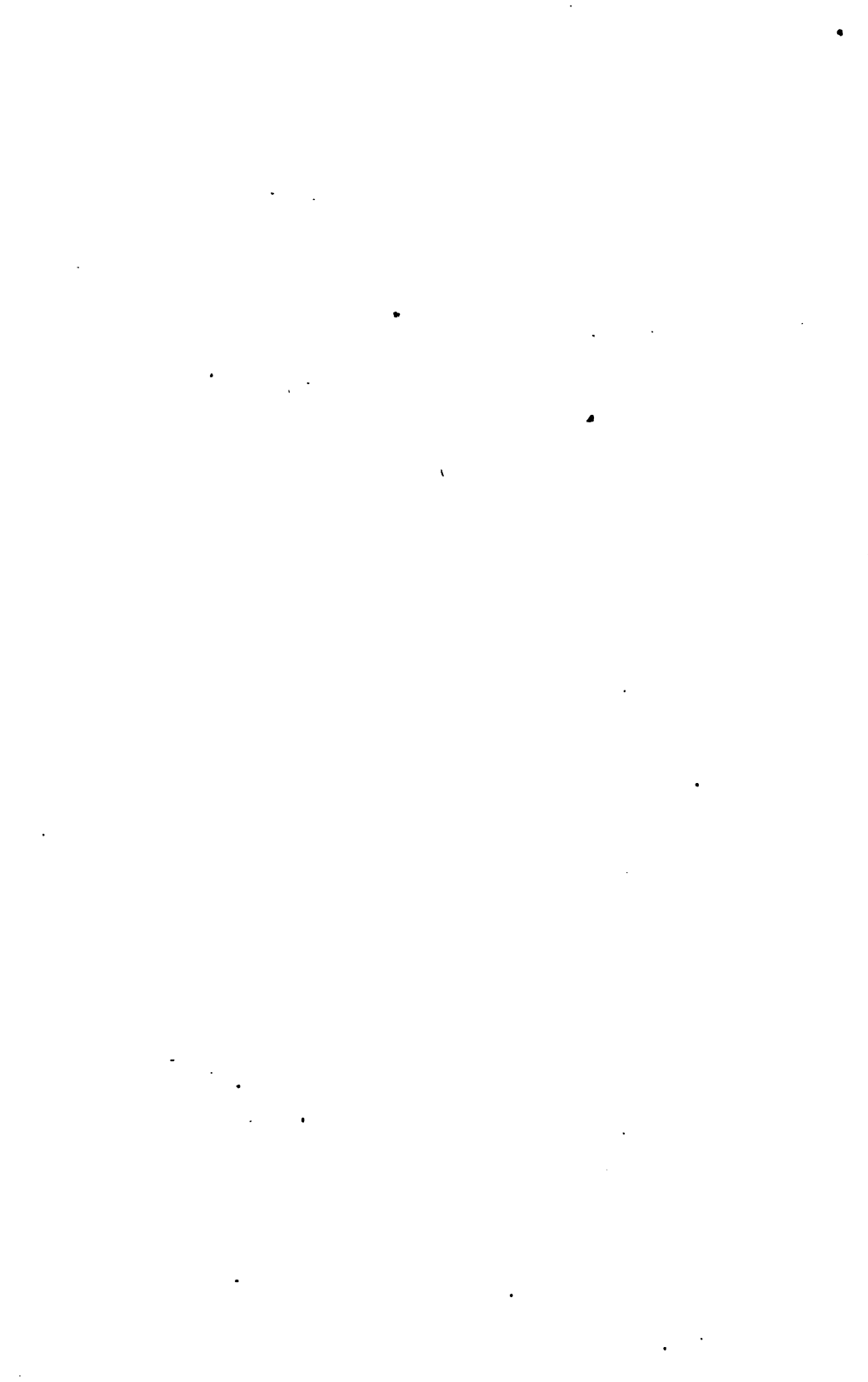
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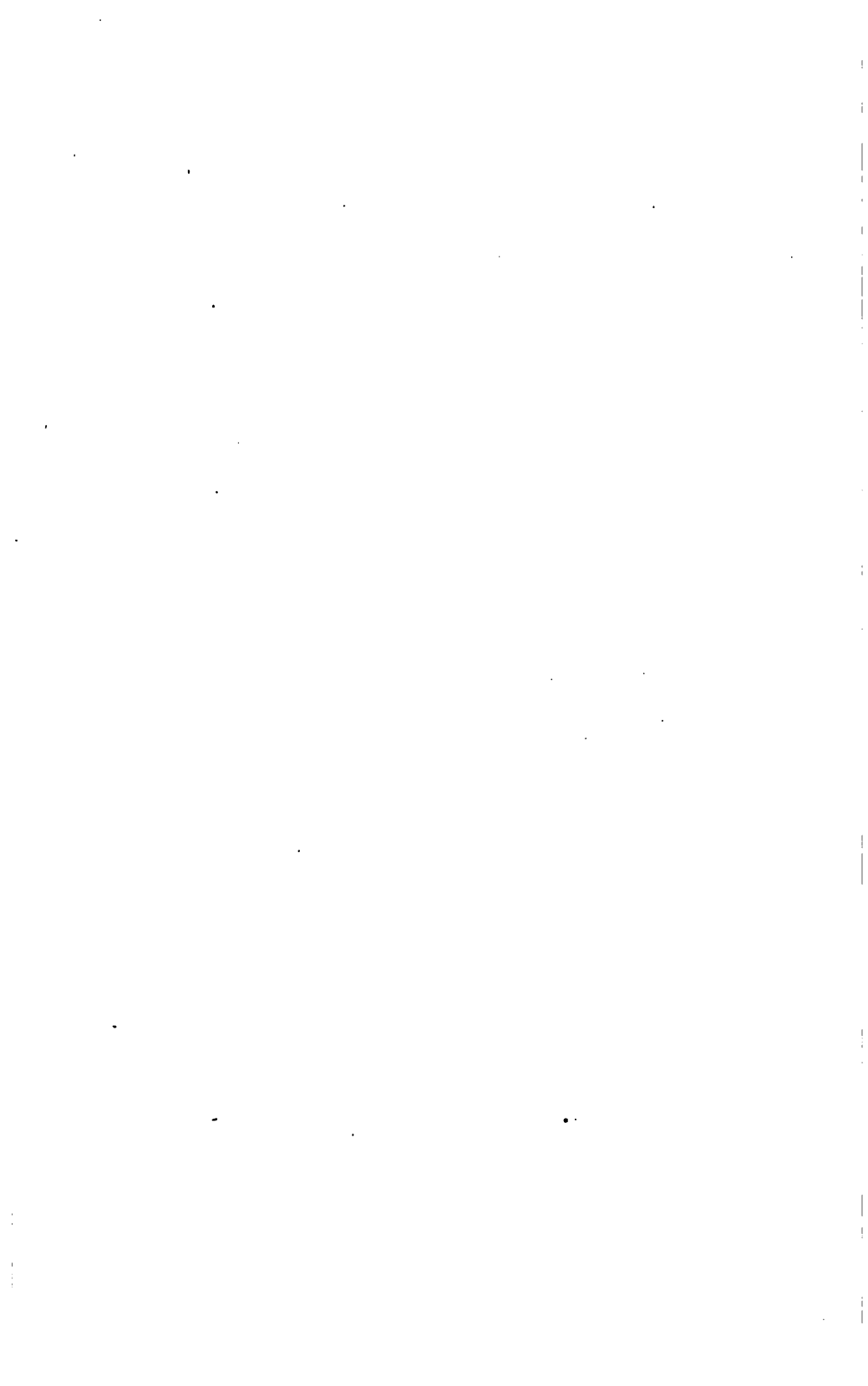
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JANUARY, 1914



Bulletin of the American Institute of Mining Engineers

SECTION I

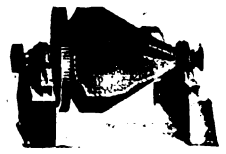
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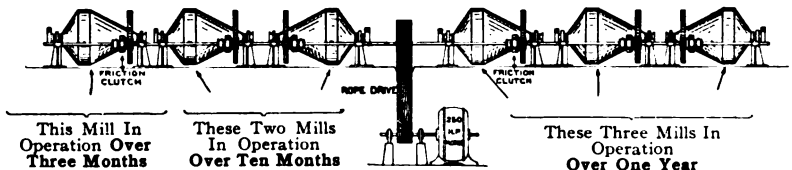
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With reference to an increase in our membership:

We submit herewith for your information a chart showing the growth of the four National Engineering Societies. While our Institute, for a time, did not rapidly increase, we are pleased to state that under present conditions a substantial gain is being made.

One of the members of this Committee, Mr. Charles F. Rand, as the result of a letter, secured 100 applications in two weeks, with others promised.

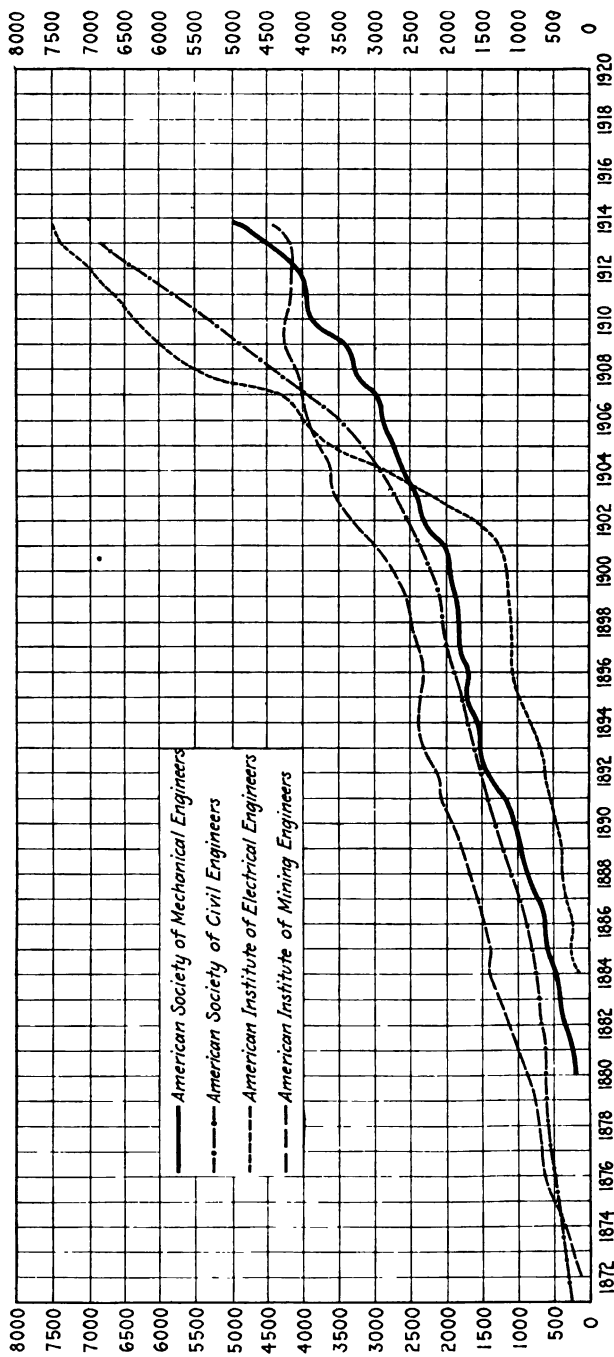
The Committee is informed that 2,000 additional good members are desired, in order that the activities of the Institute may be continued on the present scale.

Very respectfully,

Committee on Increase of Membership,

ADOLPHE E. BORIE, *Chairman.*

THOMAS T. READ, *Secretary.*



COMPARATIVE GROWTH OF MEMBERSHIP OF THE INSTITUTE AND OF OTHER NATIONAL ENGINEERING SOCIETIES
Courtesy of the American Society of Mechanical Engineers

AMERICAN INSTITUTE OF MINING ENGINEERS

29 West 39th Street, New York, N. Y.

PROPOSAL FOR MEMBERSHIP

Mr. _____

(Name in Full)

Occupation _____

Address _____

is hereby proposed by the undersigned, as a .. _____

of the American Institute of Mining Engineers.

} Signatures of three
Members or
Associates.

Place of birth _____ Year of birth _____

Education, general and technical, when, where and how acquired,
with degrees, if any.

Dates

[illegible]

Present position _____

Signature.

Dated _____ *191* _____

EXTRACTS FROM THE CONSTITUTION.

ARTICLE II.—MEMBERS.

SEC. 1. The membership of the Institute shall comprise four classes, namely: 1. Members; 2. Honorary Members; 3. Associates; 4. Junior Members. * * *

SEC. 2. The following classes of persons shall be eligible for membership in the Institute, namely : as Members, all professional mining engineers, geologists, metallurgists, or chemists, and all persons actively engaged in mining and metallurgical engineering, geology, or chemistry ; as Associates, all persons desirous of being connected with the Institute who in the opinion of the Board of Directors are suitable.

As Junior Members, all students in good standing in engineering schools who have not taken their degrees and who are nominated by at least two of their instructors. * * *

Every candidate for election as a Member, Associate, or Junior Member must be proposed for election by at least three Members or Associates, must be approved by the Committee on Membership, as prescribed in the By-Laws, and must be elected by the Board of Directors.

Aug. 14, 1906.

Bequest of

Erasmus Darwin Leavitt.

BULLETIN OF THE AMERICAN INSTITUTE OF MINING ENGINEERS

No. 85

JANUARY

1914

Published Monthly by the American Institute of Mining Engineers at 212-218 York St., York, Pa., H. A. WISOTZKEY, Publication Manager. Editorial Office, 29 West 39th St., New York, N. Y., BRADLEY STOURGTON, Editor, F. O. PIERCE, Asst. Editor. Cable address, "Aime," Western Union Telegraph Code. Subscription (including postage), \$10 per annum; to members of the Institute, public libraries, educational institutions and technical societies, \$5 per annum. Single copies (including postage), \$1 each; to members of the Institute, public libraries, etc., 50 cents each.

Application made for second class entry, Jan., 1914, at the post office at York, Pa., under the Act of March 3, 1879.

Annual Meeting, February 17 to 19, 1914.—The following Committees have been appointed to have charge of the arrangements for the Annual Meeting in New York City:

General Committee: Louis D. Huntoon, Chairman; Arthur S. Dwight, Vice-Chairman; W. deL. Benedict, George F. Kunz, Thomas T. Read, E. Maltby Shipp.
Reception Committee for Each Day: Chairmen to be announced later.
Banquet Committee: Theodore Dwight, Chairman.
Luncheon Committee: E. Maltby Shipp, Chairman.
Ladies' Committee: Mrs. Arthur S. Dwight.
Badge Committee: George F. Kunz, Chairman; E. Maltby Shipp, Vice-Chairman.
Program Committee: Thomas T. Read, Chairman.
Bureau of Registration and Information: Burr A. Robinson, Chairman.

In announcing the New York attractions during February, we call particular attention to the American Museum of Natural History. There is very much in this Museum of interest to the members of the Institute, including the largest collections in the country of:

Minerals;

Gems and Gem Materials (including the famous Morgan collection);

Meteorites;

and including also collections of general geology, of vertebrate and invertebrate palæontology, and a large size model of the Copper Queen mine at Bisbee, Ariz., on a scale of 24 ft. to the inch, and showing the details of surface and underground workings. This model was presented to the Museum by Dr. James Douglas, Honorary Member and Past President of this Institute.

BOARD OF DIRECTORS

Meeting of Dec. 19, 1913.—The President reported the appointment of the Committee on Junior Members and Affiliated Student Societies, and the Committee on Coal and Coke, which appointments were approved.

The President was authorized to appoint the members of a Committee on Safety and Sanitation.

The President appointed the Finance Committee of the Institute as a Committee to audit the accounts of the Treasurer (By-Law V).

On the recommendation of the Executive Committee, Charles F. Rand was appointed a representative of this Institute on the Board of Trustees of the United Engineering Society for a term of three years (By-Law XIV of the Institute, By-Law XI of the U.E.S.).

The Executive Committee reported that it had passed the following resolutions:

That the next summer meeting of the Institute be held at Salt Lake City during Aug. 10 to 14, 1914, inclusive;

That an exchange of the *Bulletin* and *Transactions* be made with the Canadian Bureau of Mines;

That a sum of \$50 be contributed for the year 1914 to the Commission publishing the Annual Tables of Physical and Chemical Constants;

That the Secretary be given power to reduce at his discretion the number of exchanges between the *Bulletin* and other publications which are not retained as a permanent part of the Library;

That the contract for binding Volume XLV of the *Transactions* be awarded to the Butler, Ward Co., in accordance with their bid of Nov. 21, 1913;

That Volume XLVI of the *Transactions* be entitled "The Montana Volume," and that these words be placed on the back of the volume, and that the portrait of Charles W. Goodale be used as the frontispiece thereof.

A full set of the *Transactions*, in half-morocco, was donated to the Montana Local Section, and one to the Columbia Local Section.

The sum of \$25 was appropriated for the expenses of the Puget Sound Local Section.

The Secretary and the Treasurer were authorized to introduce a double-entry system of book-keeping in accordance with recommendations made.

An extension of three months' time for the payment of dues was granted to sixty-four members who had requested it.

The resignations of nine members were accepted.

The President was authorized to report to the President of the United States that it is the sense of this Board that it supports and recommends the action of the American Institute of Consulting Engineers in presenting a memorial to the President of the United States in reference to the appointment of an engineer member on the Interstate Commerce Commission.

EMMONS VOLUME ON ORE-DEPOSITS

A continuation of the "Posepny" Volume

Comprising papers descriptive of ore-deposits and discussions of their origin, edited, with an introduction, by Dr. S. F. Emmons. The volume contains also a Biographical Notice of Dr. Emmons by his associate and friend, Dr. George F. Becker, and a comprehensive Bibliographical Index of the Science of Ore-Deposits, prepared by Prof. John D. Irving, of the Sheffield Scientific School of Yale University. Dr. Emmons had finished his editorial work and written his Introduction before his lamented death in 1910; and the Volume contains his last words upon the subject to which he had given the work of his life, and on which he was justly regarded as the foremost authority.

Contents

- Genesis of Certain Ore-Deposits. By S. F. EMMONS.
 Structural Relations of Ore-Deposits. By S. F. EMMONS.
 Geological Distribution of the Useful Metals in the United States. By S. F. EMMONS. Discussion, by JOHN A. CHURCH, ARTHUR WINSLOW, S. F. EMMONS, and WILLIAM HAMILTON MERRITT.
 Torsional Theory of Joints. By GEORGE F. BECKER. Discussion, by H. M. HOWE, R. W. RAYMOND, C. R. BOYD, and GEORGE F. BECKER.
 Allotropism of Gold. By HENRY LOUIS.
 Superficial Alteration of Ore-Deposits. By R. A. F. PENROSE, JR.
 Some Mines of Rosita and Silver Cliff, Colorado. By S. F. EMMONS.
 Genesis of Certain Auriferous Lodes. By JOHN R. DON. Discussion, by JOSEPH LE CONTE, S. F. EMMONS, G. F. BECKER, ARTHUR WINSLOW, W. P. BLAKE, and J. R. DON.
 Influence of Country-Rock on Mineral Veins. By WALTER HARVEY WEED.
 Igneous Rocks and Circulating Waters as Factors in Ore-Deposition. By J. F. KEMP.
 Consideration of Igneous Rocks and Their Segregation or Differentiation as Related to the Occurrence of Ores. By J. E. SPURR. Discussion, by A. N. WINCHELL.
 Chemistry of Ore-Deposition. By WALTER P. JENNEY. Discussion, by JOHN A. CHURCH.
 Ore-Deposits near Igneous Contacts. By WALTER HARVEY WEED. Discussion, by W. L. AUSTIN.
 Ore-Deposition and Vein-Enrichment by Ascending Hot Waters. By WALTER HARVEY WEED.
 Basaltic Zones as Guides to Ore-Deposits in the Cripple Creek District, Colorado. By E. A. STEVENS.
 Geological Features of the Gold-Production of North America. By W. LINDGREN. Discussion, by W. G. MILLER and W. L. AUSTIN.
 Osmosis as a Factor in Ore-Formation. By HALBERT POWERS GILLETTE.
 Ore-Deposits of Sudbury, Ontario. By CHARLES W. DICKSON.
 Genesis of the Copper-Deposits of Clifton-Morenci, Arizona. By W. LINDGREN.
 Copper-Deposits at San Jose, Tamaulipas, Mexico. By J. F. KEMP.
 Magmatic Origin of Vein-Forming Waters in Southeastern Alaska. By A. C. SPENCER.
 Genetic Relations of the Western Nevada Ores. By J. E. SPURR.
 Are the Quartz Veins of Silver Peak, Nevada, the Result of Magmatic Segregation? By J. B. HASTINGS.
 Occurrence of Stibnite at Steamboat Springs, Nevada. By W. LINDGREN.
 Summary of Lake Superior Geology with Special Reference to Recent Studies of the Iron-Bearing Series. By C. K. LARZE.
 Geological Relations of the Scandinavian Iron-Ores. By H. SJÖGREN.
 Formation and Enrichment of Ore-Bearing Veins. (With Supplementary Paper.) By GEORGE J. BANCROFT.
 Distribution of the Elements in Igneous Rocks. By H. S. WASHINGTON.
 Agency of Manganese in the Superficial Alteration and Secondary Enrichment of Gold-Deposits of the United States. By W. H. EMMONS.
 Cognate Papers.
 Bibliography of the Science of Ore-Deposits. By J. D. IRVING, H. D. SMITH, and H. G. FERGUSON.

The volume contains 1002 pages. Price, bound in cloth, \$5; in half morocco, \$6. Both the Emmons and the Posepny Volumes on Ore-Deposits, bound in cloth, \$8; in half morocco, \$10.

READY FOR DISTRIBUTION

PERSONAL

(Members are urged to send in for this column any notes of interest concerning themselves or their fellow-members.)

Members and guests who registered at Institute headquarters during December:

William M. Peschel, Bradford, Mass.

Herbert B. Cox, Boston, Mass.

C. Q. Schlereth, Mexico, D. F.

H. W. Caldwell, Oxford, N. C.

Charles E. Schwarz, St. Louis, Mo.

Dwight Furniss, Guanajuato, Mex.

F. W. DeWolf, Urbana, Ill.

Samuel T. Wellman, Cleveland, Ohio.

Samuel S. Wyer, Columbus, Ohio.

H. H. Stoeck, Urbana, Ill.

E. Harms, Torreon, Mexico.

G. A. Roush, So. Bethlehem, Pa.

M. K. Rodgers, Los Angeles, Cal.

George F. Kunz was elected President of the New York Academy of Sciences on Dec. 15, 1913.

Archer E. Wheeler, Superintendent of the Boston & Montana Reduction Department of the Anaconda Copper Mining Co., on Jan. 1, 1914, tendered his resignation of that position, and has accepted a position as Consulting Engineer with the Union Minière de Haut Katanga, a corporation holding mining interests in Africa, with headquarters in London and Brussels.

Francis G. Fabian and **Harry E. Hall** announce their partnership under the firm name of **Fabian and Hall**, to engage in general mining and consulting work, with offices in New York City.

Stanley C. Sears, Consulting Mining Engineer and Metallurgist, announces that he has opened an office at Salt Lake City, and is prepared to examine and report upon mining properties and to undertake their management.

Fayette A. Jones is President of the State School of Mines of New Mexico.

John H. Klepinger, formerly Assistant Superintendent of the Reduction Department of the Boston & Montana smelter, has been named to succeed **A. E. Wheeler** as superintendent.

Milo W. Krejci, metallurgist at the Boston & Montana smelter, has been named to succeed **J. H. Klepinger** as Assistant Superintendent.

Arthur L. Walker, who has been laid up with a severe attack of typhoid fever, is on the road to recovery.

Herbert Haas, of San Francisco, has been appointed Metallurgical Engineer of the U. S. Bureau of Mines.

Welton J. Crook has resigned his position as Chief Chemist of the Pacific Coast Steel Co., San Francisco, Cal., to accept an appointment as Professor of Metallurgy at the South Dakota State School of Mines, Rapid City, S. D.

Copies of Volume X of the Transactions Wanted.—Owing to the scarcity of Volume X, the Secretary of the Institute has been authorized to offer the sum of \$10 each for these volumes bound in half-morocco, or \$9 each bound in paper. In the event of not being able to secure a sufficient number of these volumes at these prices, the volume will be republished, after which copies will not be bought by the Institute.

POSITIONS VACANT

Position as superintendent of all-sliding cyanide plant in Montana will be open in spring. Thoroughly experienced man wanted. No. 6.

Position as engineer for iron-mining company in Virginia is open. Single man with experience in underground surveying preferred. No. 7.

ENGINEERS AVAILABLE

(Under this heading will be published notes sent to the Secretary of the Institute by members or other persons.)

Member, 34 years old, married, nine years responsible position in South America, excellent knowledge of Spanish, Latin-American people and customs, with present employer seven years, six years as manager and legal representative of a mining company, desires to make a change April, 1914. Prefers position requiring energy, executive ability, business tact and practical knowledge dealing with political and legal authorities, rather than strictly technical position. No. 35.

Technical graduate, married, with four years' experience in assaying, surveying, sampling, and mine supervision in Utah and Mexico, open for engagement. No. 37.

Member, aged 28, desires opening on engineering or sales force of machinery house, or manufacturing concern. Twelve years' experience, in smelters, cyanide plants, concentrators and gold dredges, steam, gas and electric machinery and mechanical drafting. At present foreman for a silver-lead company. No. 40.

Member, technical graduate, aged 37, just returned from abroad, with nine years' experience in smelting, converting, refining, assaying and general laboratory work, also experienced in construction work, mining and mine valuation, ore dressing and concentrating, desires position as assayer, chemist, foreman, superintendent's or manager's assistant with gold, silver, copper or lead concern. Would go anywhere if climatic conditions were bearable. No. 41.

Member, graduate mining and metallurgical engineer, 39 years old, married, with 16 years' experience in mining and in operation and construction of concentrating and cyaniding mills in United States, Mexico and Nicaragua, desires position with good company. Salary secondary consideration. No. 42.

Member, graduate metallurgist who has specialized in both theory and practice of treatment of gold and silver ores, desires position as assistant superintendent or superintendent. At present foreman in large stamp mill in Nevada. Married, aged 30 years. No. 43.

Member, graduate mining engineer, 33 years old, specializing in coal mining, is open for engagement as manager. Minimum salary \$5,000 annually. Can furnish references concerning integrity and ability. No. 44.

Member, mining engineer and metallurgist, graduate of Royal School of Mines, London, with 18 years' experience in Latin America in the mining and metallurgy of gold, silver and copper ores, open for engagement Jan. 1. Speaks and reads Spanish. Has a thorough knowledge of Spanish mining law. No. 45.

Graduate mining engineer, aged 38, with broad general experience in mining common precious and base metals, except iron, is open for position

as engineer for exploration company or as manager or superintendent of operating mine. No. 46.

Technical graduate, aged 27, with three years' experience in mill and smelter construction and operation, familiar with the smoke problem, open for engagement. No. 47.

Member, graduate engineer, 33 years old, open for engagement Feb. 1, as superintendent of development or construction. Three years' experience in Michigan copper country, seven years in Mexico in charge of small properties, two years in present position as construction engineer for one of largest hydro-electric plants in United States. No. 48.

Mining engineer, technical graduate, desires position as mine superintendent or foreman. Nine years' varied experience. Four years superintendent of silver-gold properties in Mexico. At present chief engineer of large copper company. No. 49.

NEW YORK LOCAL SECTION

Executive Committee

LOUIS D. HUNTOON, *Chairman.*

ARTHUR S. DWIGHT, *Vice-Chairman.*

THOMAS T. READ, *Secretary*, Woolworth Bldg., New York, N. Y.

E. MALTBY SHIPP, *Treasurer.*

GEORGE F. KUNZ.

W. DE L. BENEDICT.

Meeting, Nov. 20, 1913

A meeting of the New York Local Section of the American Institute of Mining Engineers, in joint session with the American Electrochemical Society, was held at the Engineering Societies Building, 29 West 39th Street, New York City, Nov. 20, 1913.

Mr. Lawrence Addicks, Chairman of the American Electrochemical Society, presided at the meeting, in conjunction with Mr. Louis D. Huntoon, Chairman of the New York Local Section of the American Institute of Mining Engineers.

The Chairman announced the subject to be discussed at the meeting as follows:

As this is a joint meeting of the New York Sections of the Electrochemical Society and the Institute, Mr. Huntoon has insisted that I share the responsibilities of the chair to the extent of introducing the speakers.

There will be no discussion between the papers, but Mr. Huntoon will take the chair at the end of the hour and it is hoped that the discussion of the papers as a whole at that time will be not the least instructive part of the evening.

(The technical discussion is printed on pp. 163 to 176 of this *Bulletin*.)

IRON AND STEEL COMMITTEE

ALBERT SAUVEUR, *Chairman.*A. A. STEVENSON, *Vice-Chairman.*HERBERT M. BOYLSTON, *Secretary*, Abbot Bldg., Cambridge, Mass.

John Birkinbine,
 William H. Blauvelt,
 James Gayley,
 Henry D. Hibbard,
 Henry M. Howe,
 Robert W. Hunt,
 J. E. Johnson, Jr.,

William Kelly,
 Charles Kirchhoff,
 Richard Moldenke,
 Joseph W. Richards,
 C. F. W. Rys,
 E. Gybbon Spilsbury,

J. S. Unger,
 Felix A. Vogel,
 Leonard Waldo,
 William R. Walker,
 William R. Webster,
 Frederick W. Wood.

The following papers are assured for the Iron and Steel sessions of the February meeting of the Institute:

- H. M. Howe and A. G. Levy, Notes on Over-Strain.
 R. W. Hunt, American Steel Rail Mill Practice.
 Sir Robert Hadfield, On the Magnetism of Manganese Steel.
 J. E. Johnson, Jr., The Influence on the Quality of Cast Iron Exerted by Oxygen, Nitrogen, and Some Other Elements.
 J. V. Emmons, The Surface Decarbonization of Tool Steel.
 W. S. Potter, Manganese Steel, with Relation of Physical Properties to Microstructure and Critical Ranges.
 R. H. Rice, The Turbo-Blower.
 A. N. Diehl, The Cleaning of Blast-Furnace Gases.
 R. D. Young, Notes on the Heat Treatment of Steel Castings.
 H. J. Freyn, Notes on the Utilization of Blast-Furnace and Coke-Oven Gases for Power Purposes.

It is also hoped to have papers on the Diesel Engine for Mining and Metallurgical Purposes.

The indications are that most of these papers will be widely discussed. It is hoped that any one having anything of interest to add to the discussion will submit it, no matter how brief, either orally at the meeting, or by written communication before or after the meeting.

A meeting of the Iron and Steel Committee is planned for the afternoon of Saturday, Jan. 17, 1914, in New York. Matters pertaining to the organization and general policy of the Committee will be discussed. Suggestions on these subjects from the Institute membership are always gladly received by the Committee.

It is again urged that those who desire to contribute papers for future meetings of the Institute will submit their manuscripts as far in advance of the meetings as possible, or that, at least, a statement will be made of the intention of authors to submit papers. It has been suggested by the Secretary of the Institute that it will be preferable if papers be in the hands of the Secretary at least three months in advance of the meeting at which it is intended to present them, so that papers may be preprinted and distributed in time for discussion.

HERBERT M. BOYLSTON, *Secretary.*

LIBRARY

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

AMERICAN SOCIETY OF MECHANICAL ENGINEERS

AMERICAN INSTITUTE OF MINING ENGINEERS

UNITED ENGINEERING SOCIETY

WILLIAM P. CUTTER, Librarian

The Library of the above-named Societies is open from 9 A.M. to 9 P.M. on all week-days, except holidays, from September 1 to June 30, and from 9 A.M. to 6 P.M. during July and August. The Library contains about 55,000 volumes, including sets of technical periodicals and the publications of scientific and technical societies.

Members of the Institute, with few exceptions, are forced to spend a portion of their time in localities isolated from sources of information. To these the Library can render valuable service through correspondence; letters requesting information will receive special attention. The Library is prepared to furnish references and copies of articles on mining and metallurgical subjects; to determine the existence of mining-maps, and to furnish general information as to the geology and mineral resources of all countries.

All communications should be made as definite as possible so that the information received may be what is desired and not include collateral matter which may not be of interest. The time spent in searching for such collateral matter will be saved, and the information will be sent more promptly and in more usable shape.

The members of the Institute can be of service to the Library by forwarding copies of mining-reports, maps privately issued, and similar material, which will be classified, indexed, and made available to other members. Suggestions for additions to the Library, either by purchase or personal solicitation as gifts, will be welcomed. It is hoped that members while in the city will use the Library freely, and assurance is given that most careful service will be rendered to them.

LIBRARY ACCESSIONS

New Books on Mining and Metallurgy

- COMPRESSED AIR PRACTICE. By Frank Richards. New York, 1913.
CYANIDATION IN THE MERCUR DISTRICT OF UTAH. By L. O. Howard. (Reprinted from *Salt Lake Mining Review*, Oct., 1913.) N. p., n. d. (Gift of Author.)
MINE ACCIDENT PREVENTION AT LAKE SUPERIOR IRON MINES. By D. E. Woodbridge. Technical Paper No. 30, U. S. Bureau of Mines. Washington, 1913.
SAFETY IN TUNNELING. By D. W. Brunton and J. A. Davis. Miners' Circular No. 13, U. S. Bureau of Mines. Washington, 1913.
USE AND CARE OF MINERS' SAFETY LAMPS. By J. W. Paul. Miners' Circular No. 12, U. S. Mines Bureau.

New Books on Geology and Mineral Production

- CANADA. PRODUCTION OF COPPER, GOLD, LEAD, NICKEL, SILVER, ZINC AND OTHER METALS, 1912. Department of Mines. Ottawa, 1913.

- GEOLOGY OF KALGOORLIE, WESTERN AUSTRALIA. By C. O. G. Larcombe. Melbourne, 1913. (Gift of Hill Publishing Co.)
- INDIA. REPORT OF THE CHIEF INSPECTOR OF MINES, 1912. Department of Mines. Calcutta, 1913.
- MANUAL OF PETROLOGY. By F. P. Mennell. London, 1913.
- MINERAL INDUSTRY OF NEW JERSEY FOR 1912. Bull. No. 11, N. J. Geological Survey. Trenton, 1913.
- MINERAL PRODUCTS OF THE UNITED STATES, 1903-1912. U. S. Geological Survey. 1 sheet.
- MINING AND QUARRY INDUSTRY OF NEW YORK STATE. Bull. No. 166, New York State Museum. Albany, 1913.
- UNION OF SOUTH AFRICA. Mines Department. Annual Report. Part I, Secretary for Mines and Commissioner of Mines, Natal. Part II, Government Mining Engineer, 1911, 1912. Pretoria, 1912, 1913.
- DAS STAATLICHE BLEI-ZINKERES BERGBAUTERRAIN BEI RAIBL IN KÄRNTEN. (Lead-zinc Deposits of Austria.) By Maximilian Kraus. Wien, 1913. (Gift of K. K. Berg Verwaltung III Raibl.)
- ANNUARIO DELLA INDUSTRIA MINERARIA (per Minerali Metalliferi) Metallurgica e Meccanica in Italia. Anno 1, 1913-14.
- BATAVIA. Jaarverslag der Bankatwinning. (Yearly report on Banka tin.) 1911-12.

New Books on Non-Metallic Minerals

- BELGIUM. STATISTIQUE DES INDUSTRIES EXTRACTIVE ET MÉTALLURGIQUES ET DES APPAREILS À VAPEUR EN BELGIQUE, 1912. Ministère de L'Industrie et du Travail. Bruxelles, 1913. (Gift of Ministère de L'Industrie et du Travail.)
- COAL-MINE ACCIDENTS IN THE UNITED STATES AND FOREIGN COUNTRIES. Bull. No. 69, U. S. Bureau of Mines. Washington, 1913.
- GYPSE AND SALT OF OKLAHOMA. By L. C. Snider. Bull. No. 11, Oklahoma Geological Survey. Norman, 1913.
- INVESTIGATION OF THE COALS OF CANADA. Vol. III-VI. Department of Mines. Ottawa, 1912.

New Books on Chemistry and Physics

- DICTIONARY OF APPLIED CHEMISTRY. Vol. V. By Edward Thorpe. London, 1913.
- HANDBUCH DER CHEMISCHEN INDUSTRIE DER AUSSERDEUTSCHEN LÄNDER (DIRECTORY OF THE CHEMICAL INDUSTRIES OF THE WORLD, GERMANY EXCEPTED.) Ed. 5. Berlin, 1913.

New Books on General Subjects

- BIBLIOGRAPHIE DER DEUTSCHEN ZEITSCHRIFTEN LITERATUR. Band XXXII. By F. Dietrich. Leipzig, 1913.
- POCKET GLOSSARY OF ENGLISH-GERMAN, GERMAN-ENGLISH TECHNICAL TERMS FOR ENGINEERS AND MANUFACTURERS. Compiled by J. G. Horner, translated into German by Otto Holtzmann. London, 1913.
- RELATION OF WEST VIRGINIA COALS TO THE PANAMA CANAL. Address of Ex-Governor W. A. MacCorkle before the West Virginia Coal Mining Institute, Dec. 8, 1913. N. p., n. d. (Gift of West Virginia Coal Mining Institute.)

Company Reports

- DE BEERS CONSOLIDATED MINES, LTD. Annual Report, 20-24. Kimberley, 1908-1912.

Trade Catalogues

- ACKROYD & BEST, LTD., Leeds, England. Various types of lamps.
- AMERICAN STEEL & WIRE CO., Chicago, Ill. Catalogue and Handbook on American Wire Rope. 1913.
- DEISTER CONCENTRATOR CO., Fort Wayne, Ind. General descriptive catalogue. Sept., 1913.
- FULTON IRON WORKS, St. Louis, Mo. Bull. "A" Fulton-Tosi oil engines. Nov., 1913.
- GENERAL ELECTRIC CO., Schenectady, N. Y.
Bull. 4790A. Electric mine locomotives. Feb., 1912.
Bull. 4886A. Electricity in coal mines. Aug., 1912.

- Bull. 4922. Electricity in metal mines. March, 1912.
Bull. 4939A. Electric hoists. July, 1912.
LESCHEN & SONS ROPE Co., St. Louis, Mo. Leschen's Hercules. Dec., 1913.
MESTA MACHINE Co., Pittsburg, Pa. Bull. K. Gears and rolling mill pinions.
NATIONAL PULVERIZER Co., Denver, Colo. Catalogue No. 2. National pulverizer.
PARRAL TANK SYSTEM OF SLIME AGITATION. South Pasadena, n. d. (Gift of Bernard MacDonald.)
PLATT IRON WORKS Co., Dayton, Ohio. Bull. 755. Platt high lifts and turbine pumps. Oct., 1913.
SAMSON MANUFACTURING Co., Denver, Colo. Catalogue No. 5. Samson crusher.
STURTEVANT MILL Co., Boston, Mass.
Catalogue 62A. Crushers. 1912.
Catalogue 77B. Newaygo separators. 1912.
Catalogue 79A. Ring roll mill. 1912.
Catalogue 65A. Balanced rolls. 1913.
Bull. 77W. Newaygo wet screen.
SULLIVAN MACHINERY Co., Chicago, Ill.
Bull. 58-P. Sullivan single stage, power-driven air compressors. Dec., 1913.
Bull. 58-S. Sullivan angle-compound, power-driven air compressors. Dec., 1913.
WEBSTER MFG. Co., Chicago, Ill. Webster Method. Nov., 1913.

MEMBERSHIP

NEW MEMBERS

The following list comprises the names of those persons who became members during the month of December, 1913:

Members

- ADAMS, CHARLES W., JR., Smelting, American Smelting & Refining Co.,
Murray, Utah.
- ARMSTRONG, FRANK H., Mechanical Engineer Vulcan, Mich.
- ARNOLD, JOHN B., Attorney-at-Law Room 840, 200 5th Ave., New York, N. Y.
- BOYS, HARRY R., Mining Paso Robles, Cal.
- CAVANAGH, JOHN L., Min. Engr., Nova Scotia Steel & Coal Co.,
Wabana, Newfoundland.
- CHOW, KAI CHI, Student 1120 Amsterdam Ave., New York, N. Y.
- CLARK, ARTHUR B., Mining Engineer 72 Harbour Bldg., Butte, Mont.
- CURLEY, JOHN R., State Mine Inspector P. O. Box 633, Leadville, Colo.
- DAVIS, ANGUS W., Mining Engineer,
Consolidated Mining & Smelting Company of Canada, Trail, B. C., Canada.
- DICKENSON, ERNEST H., Mining Engineer 19 W. 91st St., New York, N. Y.
- DONAHOE, FRANK T., Mining Engineer 631 W. Galan St., Butte, Mont.
- FERGUSON, JAMES C. H., Sales Agent, Midvale Steel Co.,
Monadnock Bldg., San Francisco, Cal.
- FRINK, LESTER D., Mining Engineer 503 W. Galena St., Butte, Mont.
- FULLER, MYRON L., Managing Geologist, Engineering Division,
The Associated Geological Engineers, 131 State St., Boston, Mass.
- GRAY, JOHN N. D., Mining Engineer,
19 Mansion House Road, Langside, Glasgow, Scotland.
- HAMILTON, JOHN P., Met. Engr. 431 Juneau Place, Milwaukee, Wis.
- HEWITT, EZRA A., Geol. 1107 California Ave., Butte, Mont.
- HOWARD, L. OGILVIE, Supt. Reduction Div., Old Dominion Copper Mining Co.,
Globe, Ariz.
- HOWARD, LESLIE E., Metallurgist 215 Niagara St., Lockport, N. Y.
- HUNTLEY, LOUIS G., Consulting Geological Engineer, 331 Fourth Ave., Pittsburg, Pa.
- IBE, KENROKU, Mining Engineer, Prof. of The Imperial University ... Kyoto, Japan.
- JOHNSTON, JAMES, Metallurgical Engineer, c/o Nipissing Mining Co., Ltd.,
Cobalt, Ont., Canada.
- JUDSON, WILBER, Mining Engineer Gage, New Mexico.
- KEITH, EDWARD W., Cons. Engr., Empire Zinc Co. ... 703 Symes Bldg., Denver, Colo.
- KEMP, L. W., Met., North Star Mines Co. Grass Valley, Cal.
- KOCH, GEORGE B., General Foreman, P. R. R. Foundries Altoona, Pa.
- KOHLBERG, HERBERT S., Mining Engineer, MacDonald Mine,
East Canada Smelting Co., Weedon, Que., Canada.
- LEAHY, RICHARD A., Asst. in Testing Dept., Washoe Smelter,
P. O. Box 101, Anaconda, Mont.
- LEDYARD, L. W., Mining Engineer Cobalt, Ont., Canada.
- LEGRAND, CHARLES, Cons. Engr., Copper Queen Cons. Mining Co. Douglas, Ariz.
- LIVINGSTON, ADDISON S., Mine Surveying P. O. Box 138, Morenci, Ariz.
- LIVINGSTON, IVOR, Supt. of Coal Mines Petros, Tenn.
- MCCLEARY, ELMER T., Asst. Genl. Supt., Youngstown Sheet & Tube Co.,
Youngstown, O.
- OLIVER, ROLAND B., Engineer 8 Montague du Parc, Bruxelles, Belgium.
- PAIGE, SIDNEY, Geologist, U. S. Geological Survey Washington, D. C.
- PATTEN, EARLE B., Min. Engr. Philipsburg, Mont.
- POIRIER, C. HERBERT, Mining Engineer 63 Wall St., New York, N. Y.
- RANFT, WILLIAM Q., Mine Operator 30 Church St., New York, N. Y.
- ROBINSON, CYRUS, Consulting Engineer 82 Beaver St., New York, N. Y.
- RUSTERHOLZ, RUDOLPH W., Mgr., Butte Branch, Ingersoll-Rand Co.,
109 E. Broadway, Butte, Mont.
- RYAN, EDWARD C., Blast Furnace Foreman. 513 Y. M. C. A. Bldg., Toledo, O.
- SANDBERG, AUGUST, Cons. Met. P. O. Box 804, Douglas, Ariz.
- SCHMALE, CHARLES H., Asst. Master Mechanic. P. O. Box 1335, Great Falls, Mont.
- SHOWRONSKI, STANISLAUS, Research Chemist, Raritan Copper Works,
Perth Amboy, N. J.

SMITH, LLOYD B., Consulting Geological Engineer, 331 Fourth Ave., Pittsburg, Pa.
 SOLOMON, FREDERICK W., Supt. of Concentrator..... P. O. Box 100, Miami, Ariz.
 STAPLER, JAMES B., Min. Engr., North Star Mines Co..... Grass Valley, Cal.
 STEWART, JOHN, Car Allotment Commissioner, Norfolk & Western Ry. Co.,
 Bluefield, W. Va.
 TAYLOR, HERBERT DEQ., Explosives, Atlas Powder Co..... Wilmington, Del.
 TOD, GRANT H., Tech. Representative, c/o Coast Manufacturing
 Supply Co., Livermore, Cal.
 VAN DYKE, BURTON, Supt. of Machy., Spanish American Iron Co.... Daiquiri, Cuba.
 WARD, MERWIN H., Met. Engr., Butte-Duluth Mining Co..... Butte, Mont.
 WATSON, ERNEST E., Mining Engineer..... 627 S. Idaho St., Butte, Mont.
 WILLIAMS, DANIEL J., Mining Engineer, Mgr. Continental Development Co.,
 Skeena Crossing, B. C., Canada.
 WILLIAMS, JOHN S., Genl. Mgr., Moctezuma Copper Co.... Nacozari, Son., Mexico.

Associate Members

REED, CARL S., Vice-Prest., General Equipment Co., 30 Church St., New York, N. Y.
 TACKMAN, HENRY, Student..... 253 E. 82nd St., New York, N. Y.

Junior Members

PRATT, ALLYNE F., Mining Engineer..... 727 E. 43rd St., N., Portland, Ore.
 SNEDAKER, EUGENE G., Student..... Kappa Sigma House, Golden, Colo.

Change of Status—Associate to Member

BARNUM, W. EUGENE..... of Pachuca, Mexico.
 HUANG, SAOSAN K..... of Tayeh, China.

CANDIDATES FOR MEMBERSHIP

The following persons have been proposed during the month of December, 1913, for election as members of the Institute. Their names are published for the information of members and associates, from whom the Committee on Membership earnestly invites confidential communications, favorable or unfavorable, concerning these candidates. A sufficient period (varying in the discretion of the Committee, according to the residence of the candidate) will be allowed for the reception of such communications, before any action upon these names by the Committee. After the lapse of this period, the Committee will recommend action by the Board of Directors, which has the power of final election.

Members

John Henry Adams, Birmingham, Ala.

Proposed by G. G. Crawford, F. H. Crockard, James Bonnyman.

Born, 1857, Birmingham, England. Grammar and Technical Schools of Birmingham, Eng. S. Staffordshire and East Worcestershire Institute, Dudley. 1875-80, Mining, Rolling Mill and Furnace experience, Chattanooga, Bethlehem, Pa., Pittsburg. 1880, Birmingham R. Mill. 1881-83, Chattanooga Mill; Supt. 1883-86, Supt. Mines, Tennessee, Kentucky, Georgia, Alabama. 1887-90, Sloss Iron & Steel Co., Supt. Iron Mines. 1890-1900, Pioneer Co., Gen'l Supt. Mines. 1900-06, Republic Iron & Steel Co., Supt. Mines and Asst. Mgr.

Present position: Mining Engineer and general Engineering (Consulting).

William Homer Alexander, New York, N. Y.

Proposed by R. E. Hore, P. DeP. Ricketts, J. Parke Channing.

Born, 1873, near Albany, Ore. 1882-88, Public School. 1900-02, Mining in Idaho. 1903, Mining in Colo., Leasing at Idaho Springs and Blackhawk. 1904-06, Gold dredging in Summit Co., Colo. Property now operated by Colo. Gold Dredging Co. 1907-13, Research work in connection with leaching copper ores. 1907-08, Mining Brokerage in San Francisco. 1909, Mining operations at Rossland, B. C., and Republic, Wash.

Present position: General Manager, Midland Ores & Patents Co.

William Atkins, Jr., Philadelphia, Pa.

Proposed by William H. Morris, Joseph T. Hilles, W. S. Pilling.

Born, 1883, Pottsville, Pa. 1906, Yale (Sheffield Scientific) University; degree Ph. B. Entire experience of seven years with Kingwood Coal Co., Howesville, W. Va.

Present position: Secretary.

E. T. Austin, Coniston, Ont., Canada.

Proposed by Reginald E. Hore (two additional signatures required).

Born, 1888, Whitby, Ontario, Canada. 1901-06, High School work at Whitby Collegiate Institute. 1906-09, Univ. of Toronto, Faculty of Applied Science, obtaining Honor standing for all the years. 1910-11, Post Grad. Course at Toronto, Faculty of Applied Science; degree B. A. Sc. 1907, Summer months with W. G. McFarlane, D. L. S., on land survey work in Northern Manitoba. 1909, Summer months with Mond Nickel Co., in Garson Mine. 1909-1910, Engineering Dept. of Gulf Pipe Line Co. 1911, Summer in Smelter of Canadian Copper Co. 1911-13, Instrument work for Mond Nickel Co., at Coniston, setting anchor bolts, building lines and railway lines, also timber and village construction.

Present position: General work about the Smelter under the Smelter Supt. and Designing Engineer.

Daniel Baker, Jr., Baltimore, Md.

Proposed by F. L. Grammer, D. T. Day, E. W. Parker.

Born, 1890, Buckeystown, Md. 1913, Princeton University; A. B.

Present position: Asst. Sect'y, Standard Lime & Stone Co., Baltimore, Md.

Max W. Ball, Washington, D. C.

Proposed by George Otis Smith, D. T. Day, W. C. Mendenhall.

Born, 1885, Munson, Ill. 1902, Grad. Manitou High School, Manitou, Colo. 1902-06, Colo. School of Mines, Golden, Colo.; degree E. M. 1911, National Univ. Law School. 1904, Sun and Moon M. & M. Co., Idaho Springs, Colo. 1906, W. A. Frink, Deputy Mineral Surveyor, Central City, Colo. 1906, to date, Field asst., geological aid, junior geologist, asst. geologist, U. S. Geological Survey.

Present position: Geologist, U. S. Geological Survey, Washington, D. C.

Harold Leslie Ballen.

Proposed by Thomas T. Read (two additional signatures required).

Born, 1886, Singapore, Straits Settlement. 1894-99, private instruction. 1897-1904, Modern and Technical School, Northampton, Eng. 1902-03, Associate in Art, Oxon. 1908-11, Faculty of Applied Science, Univ. of Toronto, Can. 1911, Grad. with honors in Mining Engineering. 1911-12, Surveyor and Asst. Supt., Ont. Porcupine Goldfields Development Co., Ltd. 1912-13, Shift Boss, Inspiration Consolidated Copper Co., Miami, Ariz. 1913, Assayer, Centre Star and Trail.

Present position: Asst. Mining Engineer, Le Roi Mine, Rowland (C. M. & S. Co. of Canada).

James Allen Barr, Mt. Pleasant, Tenn.

Proposed by H. Ries (two additional signatures required).

Born, 1884, Michigan. 1903, High School, Escanaba, Mich. 1907, Mich. College of Mines; B. S., E. M. 1904, Tapeman, Chicago & Northwestern Ry. 1907-8, Instructor of Metallurgy, Mich. College of Mines. 1909, Geologist in Rainier National Park for Dept. of Interior U. S. 1909, Practical Miner and Millman with Intersection Gold Mining & Milling Co., near Silverton, Colo. 1910-12, Engineer of Maintenance and Construction, Charleston, S. C., Mining and Mfg. Co. at Mt. Pleasant, Tenn.

Present position: Engineer for International Agricultural Corporation and Atlantic Phosphate & Oil Corporation, Mt. Pleasant, Tenn.

Harry B. Barren, Indiana Harbor, Ind.

Proposed by Charles H. Fulton, J. Burns Read, A. W. Smith.

Born, 1888, Cleveland, Ohio. 1910, Case School of Applied Science; B. S. degree. 1910, Ohio Steel Works, Youngstown, Ohio. 1911-12, Lorain Works, National Tube Co., Lorain, Ohio. 1913, Inland Steel Co., Indiana Harbor, Ind.

Present position: Supt. Blast Furnaces.

William Frederick Battin, Butte, Mont.

Proposed by John Gillie, C. W. Goodale, F. T. Greene.

Born, 1878, Toronto, Can. 1884-93, Ontario Public Schools and Collegiate Institutes. 1894-1900, General book-keeping and accounting experience. 1901-13, General and special experience in public accounting practice, of which about seven and one-half years has been in connection with the accounts of metalliferous and other mining and relative industries. 1908, C. P. A., Certified Public Accountant, from Univ. of Ill. 1894-1900, Various manufacturers in Toronto, Ont. 1901-03, Eastern Audit Co., Boston, Mass. 1903-04, Niles & Niles, Certified Public Accountants, N. Y. City.

Present position: 1904 to date, Member of the firm of Pogson, Peloubet & Co., and Resident Partner at Butte, Mont.

Braxton Bigelow, New York, N. Y.

Proposed by Charles F. Chandler, W. L. Benedict, Louis D. Huntoon.

Born, 1887, New York City. 1901-05, Morristown School, Morristown, N. J. 1905-07, Harvard College. 1907-10, Mass. Inst. Tech.; degree S. B. 1912-13, Miner and Millman, Goldfield Consolidated Mining Co., Goldfield, Nev. 1913, Timberman, Bunker Hill & Sullivan Mining & Concentrating Co., Kellogg, Idaho.

Present position: Unemployed.

Thomas Bass Black, Wickenburg, Ariz.

Proposed by A. R. Mackay, W. E. Defty, Fay W. Libbey.

Born, 1886, Pipestone, Minn. 1905-09, Mass. Inst. of Technology; degree Bachelor of Science. 1904, Five months with Revenue Mine, Norris, Mont.

Present position: 1909 to date, Vulture Mines Co., Wickenburg, Ariz.

Charles W. Boise, Brussels, Belgium.

Proposed by M. K. Shaler, S. H. Babb, L. W. Mayer.

Born, 1884, Hope, N. D. 1904-08, Univ. of North Dakota, School of Mines; degree of Mining Engineer. 1908-11, Santa Rita Mining Co., and Chino Copper Co., Santa Rita, N. M. 1911-13, Société Internationale Forestière et Minière du Congo, Brussels.

Present position: Engineer, Société Internationale Forestière et Minière du Congo.

Harlan Hurlbut Bradt, New York, N. Y.

Proposed by J. F. Kemp, H. S. Munroe, W. J. Mellard.

Born, 1890, Ishpeming, Mich. 1910-12, Univ. of Wis.; special course in geology. 1912-13, Stanford Univ., Columbia Univ. 1906, Detroit Salt Mining Co., Mich. 1907, A. P. Silliman, Min. Engr., Hibbing, Minn. 1908-10, Exploration in Canada; Vermilion Range Land Co., Minn. 1911-12, Algoma Central Ry. Co., Exploration. 1913, Wis. State Geological Survey.

Present position: Special student at Columbia University.

Angus Daniel Campbell, Cobalt, Ont.

Proposed by Reginald E. Hore (two additional signatures required).

Born, 1886, Stayner, Ont. 1904, Univ. Matriculation at Stayner High School. 1910, Diploma in Mining Engineering with honors, after three years at Toronto Univ. 1911, Completed the full course in Mining Engineering at Univ. of Toronto, degree of Bachelor of Applied Science with honors. 1907-08, Summers on engineering staff, Trent Canal. 1909, Surveyor for six months with O'Brien Mine Cobalt. 1910, Five months as engineer with the Dominion Nickel Copper Co., Sudbury.

Present position: 1911 to date, Mining Engineer, O'Brien Mine, Cobalt.

William Claude Campbell, Rhodesia, So. Africa.

Proposed by Thomas T. Read, Reginald E. Hore, W. G. Miller.

Born 1881, Keene, Ont., Can. 1894-99, Peterboro, Ont., Collegiate Inst. 1899-1903, Royal Military College, Kingston, Can. 1903-05, School of Practical Science, Toronto University. Summers 1902-05, Grand Trunk Pacific Ry., Transitman, etc.; Dominion Govt. work, Trent Canal. 1906, Topographer with Bureau of Mines, Ont., on Map of Cobalt Area. 1907, Examining Engineer and Inspecting for New Ontario Development Co. Worked as Miner, Timberman, etc., in Utah, Nevada, California.

Present position: Asst. Engineer with British South Africa Co.'s Mines Dey. Co., Rhodesia, So. Africa.

Everett Carpenter, Bartlesville, Okla.

Proposed by E. W. Parker, M. R. Campbell, G. H. Ashley.

Born, 1884, Holloy, Kan. 1907-11, Student University of Oklahoma, Major Geology; degree B. A. 1908, Field Asst. Okla. Geol. Survey. 1909, Field Asst., Okla. Geol. Survey and U. S. Geol. Survey. 1910, Office and Field Asst., U. S. Geol. Survey. 1911-12, Junior Geologist, U. S. Geol. Survey. 1913, Geologist Quapaw Gas Co.

Present position: Geologist Quapaw Gas Co.

Thomas Willard Cavers, Copperhill, Tenn.

Proposed by J. W. Allen, J. A. Risque, W. S. Harper.

Born, 1899, Carleton Place, Ont., Can. 1904, Grad. Queen's University, Kingston, Can.; degree B. S. in Mining and Metallurgy. 1904, Chemist, Canadian Smelting Works, Trail B. C. 1905, Chemist, Canadian Cons. Copper Co. 1906, Member firm Caludet & Co., Rossland, B. C. Experimental Laboratory. 1908, Chemist, Tenn. Copper Co., Copperhill, Tenn.

Present position: Smelter Supt., Tenn. Copper Co.

Charles H. Clapp, Tucson, Ariz.

Proposed by H. Ries, W. Lindgren, Edward E. Bugbee.

Born, 1883, Boston, Mass. 1901-05, Mining Engineering and Geology, Mass. Inst. Tech.; S. B. degree. 1907-10, Geology, Mass. Inst. Tech.; Ph. D. 1911, Geology, Harvard Univ. 1905-07, Instructor in Mining and Geology, Univ. of North Dakota, and Asst. State Geologist of North Dakota. 1907-11, Instructor of Geology, Mass. Inst. Tech. 1908-13, Geologist with Canadian Geological Survey.

Present position: Professor of Geology, Univ. of Ariz.

Eugene B. Clark, Chicago, Ill.

Proposed by F. A. Vogel, E. A. S. Clarke (one additional signature required).

Born, 1873, Dist. of Col.

Present position: Vice-Pres. and Gen. Mgr. American Sintering Co.

Patrick Francis Clark, Spokane, Wash.

Proposed by J. McD. Porter, L. K. Armstrong, Charles P. Robbins.

Born, 1850, Ireland. Practical Miner. 1873, Plumas Eureka Mines, Cal. 1874, Comstock Lode, Nev. 1875, Shift Boss, Old Telegraph and Ophir Mines, Utah. 1876, Alice Mine, Butte, Foreman. 1880, Foreman, Anaconda, Butte. 1881, Foreman, Moulton Mine, Butte. 1887, Mgr. Poorman Mine, Cœur d'Alene, Hecla Coeur d'Alene. 1895, Mgr. War Eagle Mine, B. C. 1898, Mgr. Republic Mine, Wash. 1910, Director, Standard S. L., B. C.

Present position: Vice-Prest. Standard S. L., B. C.; Prest. Bullwhacker Mine, Butte.

Joseph Hunter Cooke, Gisborn, Utah.

Proposed by A. K. Tiernan, Frank Anderson, J. C. Dick.

Born, 1883, Salt Lake City. 1899, Grad. San Francisco Public School. 1900, Course of Technical subjects under private instructor. 1901, Rodman, with Engineer Corps of Southern Pacific Ry. 1902, Engaged in mining in Utah, Nev. and Mont. 1903, Supt. of Pittsburg & Utah Gold, Silver, Copper & Lead Mining Co. 1904, Sampler and shift boss at Newhouse. 1907-08, Engaged in mining in Alaska. 1909, Boston Con. Mill, Garfield, Utah.

Present position: 1910 to date, Manager, Mono Development Co., Gisborn, Utah.

William M. Corse, Buffalo, N. Y.

Proposed by Joseph W. Richards, William H. Bassett, Bradley Stoughton.

Born, 1878, Malden, Mass. 1885-95, Mass. Public Schools. 1895, Mass. Inst. of Technology; degree S. B. 1899-1901, Chemist, Wm. S. Merrell Chemical Co., Cincinnati. 1901-03, Chemist, Detroit White Lead Works, Detroit, Mich. 1903-09, Foundry Supt. and Asst. Supt., Detroit Lubricator Co., Detroit, Mich. 1909, Asst. Manager, Mich. Smelting & Refining Co. 1901-13, Works Manager, Lumen Bearing Co., Buffalo, N. Y.

Present position: General Manager, Empire Smelting Co., Depew, N. Y.

Dexter Parshall Cooper, Keokuk, Iowa.

Proposed by B. H. Parsons, O. B. Perry, B. R. Value.

Born, 1880, Rushford, Minn. 1902-04, Preparatory School, St. Gallen, Switzerland. 1904-08, Royal Polytechnical School at Karlsruhe, Germany; M. E. 1897-98, Platt Iron Works, Stone Quarries, Ellenville, N. Y. 1898-99, Chicago Bridge & Iron Co. 1899-1900, Platt Iron Works, Cement Inspector, Island of Jamaica, W. Indies. 1900-02, F. S. Pearson, Quarries in Brazil. 1908-10, Reconnaissance work for H. L. Cooper. 1910-13, Quarry, Dam Construction and Cement Testing work, Hydraulic Engineering Co. of Maine, Keokuk, Iowa.

Present position: General Superintendent.

George Watson Creighton, Steelton, Pa.

Proposed by R. V. McKay, Charles P. Turner, F. D. Carney.

Born, 1890, Philadelphia, Pa. 1911, Princeton Univ.; C. E. 1911 to date, With the Penn. Steel Co., Steelton, Pa.

Present position: First Asst. Supt. Nos. 1 and 2 Blooming Mills and Rail Mill.

John Alexander Dresser, Sault Ste. Marie, Can.

Proposed by Reginald E. Hore, C. K. Leith, C. V. Corless.

Born, 1866, Richmond, Pa. 1887-93, McGill University, Montreal; degree B. A. & M. A. in Geology. 1894-95, Harvard Univ. 1896-1906, Principal, St. Francis College, Richmond, and field work, Geol. Survey of Canada; work, Copper deposits of Southern Quebec. 1906-07, Explorations in Northern Quebec. 1907-08, Lecturer in Geol., McGill Univ. 1909-11, Geologist, Geological Survey of Canada; work, Asbestos and Chromite of Quebec.

Present position: 1911 to date, Manager Lands Dept. of Algoma Central & Hudson Bay Ry. and Algoma Eastern Railway, Sault Ste. Marie, Can.

John B. Emerson, St. Louis, Mo.

Proposed by J. D. Robertson, Arthur Thacher, H. O. Wheeler.

Born, 1879, Fond du Lac, Wis. 1895-99, Univ. of Wis., B. S. in Chemistry. 1899-1905, Chemist, Ill. Steel Co., Joliet, Ill. 1905-07, Metallurgist, Mt. Vernon Car Mfg. Co., Mt. Vernon, Ill. 1907-08, Chemist and Metallurgist, R. W. Hunt & Co., St. Louis, Mo. 1908, St. Louis Manager, R. W. Hunt & Co.

Present position: St. Louis and Southwestern Manager, R. W. Hunt & Co., Bureau of Inspection, Tests, and Consultation.

Francis Gordon Fabian, New York, N. Y.

Proposed by J. F. Kemp, Robert Peele, Bradley Stoughton.

Born, 1884, Chicago, Ill. 1890-97, Private and public schools, Evanston, Ill. 1897-1901, Evanston, Ill., Township High School. 1901-03, Cornell Univ.; degree M. E. 1905-07, School of Mines, Columbia Univ.; Engineer of Mines. 1908, Engr. Montezuma Mines, Inc., Montezuma, Costa Rica. 1908-09, Supt. Three B B B Mining & Improvement Co., Howbrit, Colo. 1909, Engineer and Foreman, Cuba Mining & Milling Co., Guanajuato, Mexico. 1910, Asst. Chief Engr., Compania Real del Monte y Pachuca, Mexico. 1910-12, Real Estate, Cincinnati, Ohio. 1912-13, Manager, Utica Steam Gauge Co., Frankfort, N. Y.

Present position: Mining and Consulting Engineer, Fabian & Hall, New York City.

Aubrey Fellows, Collinsville, Ill.

Proposed by Herman Garlich, H. A. Wheeler, Arthur Thacher.

Born, 1885, Salisbury, Mo. 1901, Grad. Salisbury High School. 1902-03, Pritchett College, Glasgow, Mo. 1907, B. S. Mining Engineering, Missouri School of Mines. 1907-09, Picher Lead Co., Joplin, Mo., laboratory, office, general foreman. 1909, St. Louis Smelting & Refining Co., Collinsville, Ill.

Present position: Supt., Sublimed Lead Plant.

Siegfried Fischer, So. Bethlehem, Pa.

Proposed by Joseph W. Richards, Benjamin L. Miller, H. Eckfeldt.

Born, 1882, Zurich, Switzerland. 1897-1900, St. Gall, Switzerland. 1900-03, Polytechnicum, Zurich. 1903-05, Charlottenburg and University of Leipzig. 1905-07, Columbia Univ., N. Y.; Grad. as Chemist. 1907-08, American Casein Co. 1908-09, B. F. Stuism & Co., Buffalo, N. Y. 1909-10, Westminster College, Colo., Chemistry and Physics. 1910-12, Colo. School of Mines, Instructor in Elect. Met. and Phys. 1913, Mining and Met. Repeat Work.

Present position: Instructor of Met., Lehigh University.

George E. Fisher, Cleveland, Ohio.

Proposed by C. A. Grasselli, Charles F. Rand (one additional signature required).
Present position: Director, Grasselli Chemical Co.

Thomas Bledsoe Foust, Cumberland Furnace, Tenn.

Proposed by Graham Macfarlane, Charles F. Rand (one additional signature required).

Born, 1882, Winston-Salem, N. C. 1898, Grad. from Public Schools, Winston-Salem, N. C., and entered Univ. of N. C. One year with R. J. Reynolds Tobacco Co. 1902-03, Univ. of N. C., B. S., Dept. of Chemistry. 1903, Chemist, Bon Air Coal & Iron Co., Allens Creek, Tenn. 1905, Night furnace man at same plant. 1906, Asst. Supt. 1907, Supt. Red River Furnace Co., Clarksville,

Present position: 1912 to date, General Supt. Warner Iron Co., Cumberland Furnace, Tenn., in charge of mines and quarries.

Frank Henry Fovargue, Terlingua, Texas.

Proposed by Charles H. Fulton, F. A. Fahrenwald, Walter E. Koch.

Born, 1878, Cleveland, Ohio. 1898, Grad. Cleveland West High School. 1899, Spencian College, Cleveland. 1901-02, Cleveland Law School. 1902-06, Mining Engineering course at Case School of Applied Science; B. S. degree. 1898-1900, Bookkeeper with Garfield Savings Bank Co., Cleveland, Ohio. 1900-02, Bookkeeper with the National Malleable Castings Co., Cleveland. 1902-06, College. 1906-08, Field Engineer for the U. S. Coal & Oil Co., Holden, W. Va. 1908-10, Supt., Blain Mining & Reduction Co., Gothic, Colo. 1910-1911, Associated with O. H. Aikine, Gunnison, Colo.; Passed examination for U. S. Deputy Mineral Surveyor at Denver, Colo. 1912, Engineer, the Chisas Mining Co.

Present position: Supt., The Chisas Mining Co., Terlingua, Texas.

John P. Fried, Boston, Mass.

Proposed by S. P. Sharples, A. H. Eustis, W. E. C. Eustis.

Born, 1866, Pittsburg, Pa. Prepared for college, but did not enter. Three years in office of S. K. Sharples, Boston. 1886, Engaged in oil business in Penn. as refiner.

Present position: Manager, United Chemical & Nickel Co. of Floyd Co., Virginia.

George Frielinghaus, Essen Ruhr, Germany.

Proposed by (three signatures required.)

Born, 1855, Dortmund. 1876, Schools, Dortmund. 1877-80, Univ. Tubingen, Royal Mining Academy and Univ. of Berlin. 1880-84, In the service of the Prussian Gov. 1885-88, Prussian Gov. service at the Royal Coal Mines as Mining Engineer. 1888-1891, South West African Protectorate as Mining Commissioner. 1892-98, Mining Director of a Royal Coal Mine, Reden near Saarbruck. 1898 to date, Krupp works, Essen Ruhr.

Present position: Member of the Board of Directors of the Fried. Krupp Actiengesellschaft, Essen Ruhr.

E. W. Furst, Cleveland, Ohio.

Proposed by C. A. Grasselli, Charles F. Rand (one additional signature required).

Present position: Director, Grasselli Chemical Co.

Frank B. Gearhart, Palmerton, Pa.

Proposed by Francis P. Sinn, G. Riggs, J. A. Singmaster.

Born, 1878, Altoona, Pa. To 1897, Public Schools. 1897-1901, Lehigh Univ.; A. C. 1901-06, Asst. Chemist, Penn. Railroad Co. 1906-10, Chemist, The New Jersey Zinc Co. (of Pa.). 1910-12, Chief of Testing Dept.

Present position: Chief of Spelter Dept., The New Jersey Zinc Co. (of Pa.).

Walter Gilman, Philadelphia, Pa.

Proposed by R. A. F. Penrose, Jr., R. H. Sanders, Edward V. D'Involliers.

Born, 1876, Philadelphia, Pa. 1891-94, North East Manual Training High School of Philadelphia. 1894-96, Joseph H. Young, Civil Engineer, Phila. 1897-1900, Haupt & Franklin, Civil Engineers, Phila. 1900-01, Chester E. Albright, Civil Engineer; Isthmian Canal Commission, Washington, D. C. 1901-13, Edward V. D'Involliers, Geologist and Mining Engineer, Philadelphia, Pa.

Present position: Associated with Edward V. D'Involliers, as Mining Engineer.

Luther Elmer Gilmore, Pottstown, Pa.

Proposed by Bradley Stoughton, A. E. Hammer, A. H. Jameson.

Born, 1882, Lowell, Mass. 1905, B. S., Mass. Inst. of Technology. 1905, Laboratories, Lackawanna Steel Co., Buffalo, N. Y.

Present position: 1905 to date, Chemist, Malleable Iron Fittings Co., Branford, Conn.

E. L. DeGolyer, Tampico, Tamps., Mexico.

Proposed by D. T. Day, E. W. Parker, A. H. Brooks.

Born, 1885, Greenburgh, Kan. 1912, Bachelor of Science, Univ. of Okla. 1906-07, U. S. Geological Survey. 1908-09, Field Geologist, U. S. Geological Survey.

Present position: 1910 to date, Geologist and Chief Geologist, Eagle Oil Co., Tampico, Mexico.

Harry E. Hall, New York, N. Y.

Proposed by J. F. Kemp, Robert Peele, Bradley Stoughton.

Born, 1887, Virginia City, Mont. 1893-94, Public schools, Ogden, Utah. 1894-98, public and private schools, Des Moines, Ia. 1899-1905, Delancy School, Philadelphia, Pa. 1905-09, School of Mines, Columbia Univ., New York. 1907, Alder Gulch Cons. Mining Co., Virginia City, Mont. 1909, Silver Bow Mine, Anaconda Copper Mining Co., Butte, Mont. 1909-10, New York Telephone Co., N. Y. City. 1910-11, Ball & Hall, Virginia City, Mont. 1911-12, Hall & McCofnell, Virginia City, Mont. 1912-13, Conn. Crushed Stone Co., New Britain, Ct.; Fabian & Hall, Mining Engineers, New York City.

Present position: Fabian & Hall, New York City.

Lester Andrew Hamilton, Steelton, Pa.

Proposed by R. V. McKay, F. D. Carney, Charles P. Turner.

Born, 1884, New York City. 1898, Grad. Public School, Jersey City, N. J. 1902, Grad. Hasbrouck Institute, Jersey City. 1906, Grad. Stevens Institute of Technology; M. E. 1906-13, Penn. Steel Co., Steelton, Pa., Operating Learner, Asst. Supt. and Supt. of Merchant Mill Dept.

Present position: Supt. of Merchant Mill Dept.

Hubert H. Harpham, Los Angeles, Cal.

Proposed by T. W. Mather, A. L. Kelley, Rush M. Hess.

Born, 1883, Alameda, Cal. 1911, Univ. of Cal.; degree B. S. 1902, Los Angeles High School. 1906, Elec. helper underground, North Star Mines Co., Grass Valley. 1907-08, Tonopah Mining Co., Tonopah, Nev. 1909-10, Geol. Dept., Kern Trading & Oil Co., Maricopa, Cal. 1909, Prospector, Jamison Mining Co., Johnsville, Cal. 1910-11, Time and Store Keeper, Ward Shaft Div., United Comstock Pumping Association, Virginia City, Nev.

Present position: Shift boss, South American Development Co., Ecuador, So. Amer.

James Heggie, Hayden, Ariz.

Proposed by Thomas T. Read, A. Eilers, Willard S. Morse.

Born, 1875, Dundee, Scotland. 1892, Grad. Joliet High School, Joliet, Ill. 1897, Grad. Univ. of Mich.; B. S. 1895, In laboratory Joliet Works of Ill. Steel Co. 1896, Laboratory of Western Electric Co., Chicago, Ill. 1897-98, Parke, Davis & Co., Manufacturing Druggists, Detroit, Mich. 1899, Detroit Gas Works, Detroit, Mich. 1899-1905, American Smelting & Refining Co., Pueblo, Colo. 1906-08, United States Smelting Co., Midvale, Utah. 1908-11, Garfield Smelting Co., Garfield, Utah. 1912-13, Hayden Plant, American Smelting & Refining Co.

Present position: Supt., Hayden Plant, American Smelting & Refining Co.

Robert Irwin Henderson, Toronto, Ont., Canada.

Proposed by W. J. Morrison, Frank C. Loring, J. W. Wilson.

Born, 1870, Toronto, Can. 1876-82, Public Schools. 1882-84, High School. 1884, Experiments in original research work in the alloys and hardening of steel and copper. Inventor and patentee of the Henderson Process for making tool steel and hardening copper.

Present position: Proprietor and Mgr. Henderson Process for hardening copper and a Director of the Canadian Tool Steel Co., Ltd.

Charles Martin Henrotin, Haileybury, Ont., Canada.

Proposed by M. B. Grover, Sydney Smith, D. John.

Born, 1876, Chicago, Ill. 1890-93, Chicago Manual Training School. 1893-97, Cornell Univ.; degree M. E., Member Canadian Mining Inst. 1897-1900, Mining in Utah. 1900-08, Mgr. Kimberley Mine, De Beers Cons. Mines, Ltd., Kimberley, So. Africa, 1908-11, Reporting and Consulting. 1911-13, Haileybury, Ont., Can., Supt. of Mines, Canadian Copper Co.; Mine Supt., Dome Mines, Ltd.

Present position: As above.

Charles Arthur Herbert, Streator, Ill.

Proposed by (three signatures required).

Born, 1879, Saginaw, Mich. 1896, Grad. Saginaw High School. 1901, Grad. Mich. College of Mines; degree B. S. and E. M. 1896, Employed by Chas. Holmes, civil engineer. 1901-04, Mining Engineer, Chicago, Wilmington & Vermillion Coal Co. 1904-06, City Engineer for City of Streator, Ill., also acting as Engineer for several Mining Companies.

Present position: 1906 to date, General Supt., Chicago, Wilmington & Vermillion Coal Co.

James B. Herreshoff, Jr., Laurel Hill, N. Y.

Proposed by W. H. Nichols, Jr., Rowland F. Hill, Robert K. Painter.

Born, 1878, London, Eng. 1900, B. S., University of Cal. 1901-1913, Nichols Copper Co., Chemist, Electrical and Mechanical Engineer and Metallurgist.

Present position: Supt., Nichols Copper Co.

Arthur E. Hodgkins, Port Henry, N. Y.

Proposed by Charles F. Rand, W. L. Cumings (one additional signature required).

Present position: Gen. Mgr., Cheever Iron Co.

Allan C. House, Cleveland, Ohio.

Proposed by M. A. Hanna, R. B. Richards, L. E. Dunham.

Born, 1886, Marion, Iowa. General education at Hill School, and Phillips Exeter Academy, also brief term at Amherst, as special student; attended no technical school. Last 3½ years with M. A. Hanna & Co., in connection with iron ore interests. Previous to this, practical experience with Oliver Iron Mining Co., properties in Minn.

Present position: M. A. Hanna & Co., and Secretary of the Wakefield Iron Co.

David L. C. Hover, Washington, D. C.

Proposed by Thomas T. Read, Robert Peele, Henry S. Munroe.

Born 1888, Washington, D. C. 1902-06, Public High Schools. 1906-10, School of Mines, Columbia Univ., New York; degree E. M. 1910-12, Chemist at Perth Amboy plant of American Smelting & Refining Co. 1913, Chemist with Mexican Dept. of same company.

Present position: Chemist, Mexican Dept. of A. S. & R. Co.

Stephen L. Kaffer, Esquida, Sonora, Mexico.

Proposed by, L. R. Budrow, R. T. Mishler, C. M. Heron.

Born, 1889, Atchison, Kan. 1895-1903, Atchison Schools. 1903-07, High School. 1907-11, Univ. of Kansas, Mining Course; B. S. 1911-13, Experience with Tigre Mining Co., Assay work, filters, tube milling, refining, and solution man. Experience in mill design and construction.

Present position: Solution man with Tigre Mining Co.

William W. Keefe, Pittsburg, Pa.

Proposed by G. S. Rice, J. A. Holmes, S. A. Taylor.

Born, 1867, Mauch Chunk, Pa. 1891-1902, Supt. Pawnee & Himrod Coal Cos., Danville, Ill. 1903-1907, General Supt., Pittsburgh Coal Co. 1907-09, General Mgr. Mines, Monongahela River Cons. Coal & Coke Co. 1910-14, Prest., Pittsburgh Terminal R. R. & Coal Co. 1910-13, Vice-Prest., Millburn Coal & Coke Co., Charleston, W. Va., and Prest., Keefe Coal & Coke Co., Pittsburg, Pa. 1909-11, Prest., Aurora Mines Co.

Present position: 1911 to date, Prest. Bessemer Coal & Coke Co.

Cornelius Douwe Keen, Shreveport, La.

Proposed by Anthony F. Lucas, D. T. Day, E. W. Parker.

Born, 1886, The Hague, Holland. 1899-1904, High School, The Hague, Holland. 1904-09, Technical Univ., Delft, Holland; degree of Mining Engineer. 1908-09, Asst. in Mineralogy at the Technical Univ., Delft, Holland. 1909-10, Asst. Engineer at the Govt. coal mines, Holland. 1910-11, Geologist for the Orion Oil Co., in Roumania.

Present position: 1911 to date, Manager for Mr. Jan Koster's oil interests in Louisiana.

James A. Kelly, Seattle, Wash.

Proposed by Amos Slater, Chester F. Lee, H. D. McLeod.

Born, 1877, Waterford, N. Y. 1896-97, University of Wash. 1898, N. P. Coal Co., Roslyn, Wash. 1889, Asst. Supt., Beaver Coal Co., Ore. 1900-01, Chief Engineer Cook Inlet Coal Fields Co. 1902, Asst. Engr., Stone & Webster. 1903, Chief Engr., Marshall Coal & Coke Co., Ashford, Wash. 1904, Chief Engr., Taylor Creek Ditch Co., Noma. 1905-08, Partner, Kelly & Chapman, Civil and Mining Engrs. 1909-10, Chief Engr., Denny Rentan Clay & Coal Co., Taylor, Wash. 1911-13, Chief Engr., Carbon Coal & Clay Co., Seattle, Wash.

Present position: General Manager, Pocahontas Development Co., Seattle, Wash.

Richard B. T. Kiliani, New York, N. Y.

Proposed by H. W. Hardinge, F. W. Cooke, Charles F. Rand.

Born, 1888, Halle, Germany. 1904-06, Columbia College. 1906-10, Cornell Univ. 1909, Summer with Kansas City Southern Ry., as rodman. 1911-12, With Delaware & Hudson Co. as draftsman, transitman, and resident engineer.

Present position: 1912 to date, Secretary Hardinge Conical Mill Co., 50 Church St., New York City.

Oscar M. Kuchs, Tooele City, Utah.

Proposed by W. Wraith, W. D. Thornton, J. W. Allen.

Born, 1882, Doniphan, Kan. 1886-99, General Education, Doniphan and Atchinson, Kan.; St. Joseph, Mo.; Lawrence, Kan. 1899-1904, Kansas Univ., School of Mines; degree B. S. 1905-06, Freiberg, Saxony; Post Grad. work. 1903-04, Old Dominion Copper Mining Co., Mechanical Dept.; Silver Lake Mines, Mechanical Dept. 1906-10, Anaconda Copper Mining Co., Testing Dept., Chemical Laboratory. 1910 to present, Chief Chemist, International Smelting & Refining Co.

Present position: Acting Supt., I. S. & R. Smelter, Tooele, Utah.

Everett Bodine Lathan, Taft, Cal.

Proposed by William Campbell, H. S. Munroe, Robert Peele.

Born, 1874, Charlotte, Mich. 1893-94, Albion College, Albion, Mich. 1895-96, Detroit College of Law; degree LL. B. Admitted to Bar. 1896-97, Harvard Univ., special work in chemistry. 1906-09, Columbia Univ. School of Mines; degree E. M. 1909-10, Columbia Univ., Graduate work in Geology, Mineralogy, Electro-Chemistry; degree A. M. 1910-12, Field Geologist, Kern Trading & Oil Co., Southern Pacific R. R., San Francisco, Cal.

Present position: Geologist, 1912 to date, Kern County Oil Protective Association, Taft, Cal.

Germain Adeodat Lavoie, Beaver Mines, Alta, Can.

Proposed by J. W. Revere, H. C. Burchell, F. E. Lucas. (Six others.)

Born, 1881, Rimouski, P. Q., Can. 1902, B. A. degree, St. Joseph's College, St. Joseph's, N. B. 1905, Long course with Diploma at Royal Military College, Kingston, Ont. 1909, French Interpretation Examination, technical and literary, War office, England. 1905-10, Held Commission in Permanent Force of Can., Lecturing and giving training in Military Engineering. 1910-11, Field Engr., Dominion Coal Co., Glace Bay, N. S.; R. R. Cons. and Maintenance, Hydrographic and Land Surveys. 1911-12, Field and Underground Engineer at the Lethbridge Collieries, Ltd., Alberta. 1912, Mining Engineer, Western mine, Beaver Mines, Alta., Can.

Present position, Mining Engineer, Western Colliery, Canadian Coal & Coke Co., Beaver Mines, Alta., Can.

Arthur Garfield Levy, New York, N. Y.

Proposed by Henry M. Howe, William Campbell, E. J. Hall.

Born, 1881, New York City. 1888-91, Wöhlerschule and Gymnasium, Frankfurt/M, Germany. 1891-96, Private and at Oxford House School, London, England. 1896-99, Finsbury Technical College, London. 1902, B. Sc., Univ. of London, First Class honors in Chemistry. 1899-1900, Passed Examinations of the Institute of Chemistry. 1905, Fellow of the Institute of Chem. (F. I. C.). 1899-1903, Asst. analytical chemist to Stanger & Blount, Westminster, London. 1903-09, Principal asst. (chemist) to Bertran Blount. 1909 to date, Private asst. to Prof. Henry M. Howe, Columbia University, New York.

Present position: Principal Asst. to H. M. Howe.

Lewis Byron Lindemuth, Steelton, Pa.

Proposed by R. V. McKay, F. D. Carney, Charles P. Turner.

Born, 1887, Wichata, Kan. 1909-12, Penn. State College; B. S. and E. M. in Metallurgy. 1909 to date, with the Penn. Steel Co., Steelton, Pa.

Present position: Asst. Supt. Open-Hearth Department.

Charles T. Lupton, Washington, D. C.

Proposed by W. C. Mendenhall, E. W. Parker, F. L. Ransome.

Born, 1878, Mt. Pleasant, Ohio. 1894-96, High School, Mt. Pleasant, Ohio. Summers, 1900-01, Business College, Oberlin, Ohio. 1903-07, Oberlin College, Oberlin, Ohio; A. B. 1913-14, National Univ. Law School. 1897-1902, Teacher in Public Schools, Jefferson County, Ohio. 1907 to date, U. S. Geological Survey, Washington, D. C.

Present position: Associate geologist with the U. S. Geological Survey.

Fred Stephenson Norcross, Jr., Greenwood, B. C.

Proposed by W. L. Bell, Frederick Keffer, D. W. Brunton.

Born, 1884, Menominee, Mich. 1902, Public School, Menominee, Mich. 1906, Univ. of Michigan; B. S. Mech. Eng. 1908, Mich. College of Mines, Houghton; E. M. 1908-09, Engineer and Supt., Gale Creek Coal & Coke Co., Wilkinson, Wis. 1910-11, Const. Engr. and Supt., Coast Coal Co., Pittsburg, Wis. 1911, Engr., B. C. Copper Co., Greenwood, B. C. 1911-12, Supt., Rawhide Mine, Phoenix, B. C. 1913, Supt. Mines, B. C. Copper Co., Greenwood, B. C.

Present position, Supt. Mines, B. C. Copper Co.

Franklyn William Oatman, San Francisco, Cal.

Proposed by P. R. Bradley, F. W. Bradley, G. Caetani.

Born, 1890, Sacramento, Cal. 1904-08, Lowell High School, San Francisco. 1908-12, College of Mining, Univ. of Cal.; B. S. degree. 1913-14, Univ. of Cal.; grad. work in structural design and hydraulics.

Present position: As above.

Spencer May Parker, La Libertad, Nicaragua, C. A.

Proposed by M. A. Newman, H. Foster Bain, George Fairbairn.

Born, 1883, Ypsilanti, Mich. 1907, Univ. of Cal.; B. S. Fresno Copper King Mines, Assaying. 1908, Nogal, N. M., Cyaniding. 1909, with Oakdale Ore Purchasing Co., Point Richmond, Cal., shift man in cyanide plant. 1910-12, Assaying, Minas de Tajo, Mex. Associated with Roger L. Beals and Samuel C. Feneuf. 1912 to date, Mina Babilonia, La Libertad, Nicaragua, C. A.

Present position: Metallurgist.

Earl Richard Pembroke, Salt Lake City, Utah.

Proposed by J. H. Winwood, L. A. Jeffs, E. A. Wall.

Born, 1878, Salt Lake City. 1895-96, Salt Lake High School. 1896-99, Utah Univ. 1899-1900, Mass. Institute Tech. 1900-03, Columbia Univ., School of Mines; E. M. 1903-04, Genuine Mining Co., Eureka. 1904-05, Surveying. 1905-08, Mining Engineering. 1908-09, Boston & Pioche Mg. Co., Pioche, Nev. 1909-10, Mining Engineering. 1910, Mt. Gaines Cons. Mg. Co., Mariposa Co., Cal. 1911-12, Canada Mines, Ltd., Mont. 1913, Mining Engineering.

Present position: Professional Work.

Eugene Roy Pickrell, New York, N. Y.

Proposed by Frederic P. Dewey, F. A. Thomson, S. Shedd.

Born, 1885, Palouse, Wash. 1901, Grad. Palouse High School. 1903, Grad. Preparatory Dept. State College of Washington, Pullman, Wash. 1907, Grad. State College of Wash. Pullman, Wash.; B. S. degree. 1913-14, Enrolled as a Grad. Student in Chemistry Dept. New York Univ. 1907, Asst. Assayer, British Columbia Copper Co. 1908, Mining Engineer with J. Nordquist, Wallace, Idaho. 1909, Technical Asst. Assay Dept., U. S. Mint, Denver, Colo. 1910, Asst. Assayer, U. S. Assay Office, Kansas City, Mo. 1911, Met. Chemist and Assayer, U. S. Customs service, New York. 1913, Chemist in Charge, U. S. Customs service, New York.

Present position: Met., Chemist and Assayer, and Chemist in Charge, U. S. Customs service, New York City.

Joseph E. Pogue, Washington, D. C.

Proposed by J. H. Pratt, E. W. Parker, A. M. Brooks.

Born, 1887, Raleigh, N. C. 1906, A. B., Univ. of North Carolina. 1907, M. S., Univ. of N. C. 1909, Ph. D., Yale Univ. 1912, Student at Heidelberg Univ., Germany. 1909-13, Asst. Curator in charge Div. of Mineralogy and Petrology, U. S. National Museum. 1913, Associate Geologist, U. S. Geol. Survey.

Present position: Associate Geologist, U. S. Geological Survey.

Hermann Gustave Poock, Clausthal, Harz, Germany.

Proposed by George A. Camphuis, L. M. Cockerell, J. F. B. Erdlets, Jr.

Born, 1885, Halberstadt. 1903-11, Royal Mining Academy, Clausthal, Harz. 1913, degree of Diplom-Ingenieur. 1911-12, General Manager Sanga Negra Mining Comp. (Tin and Wolfram) near Encruzilhada, Rio Grande do Sul, Brazil. 1912-13, Asst. Engineer Mineral Exploration work for the Brazil Railway Comp. (coal explorations).

Present position: Studies on mines and washing plants in Germany and Austria and working in the mineralogical and metallurgical Institute of the Royal Mining Academy at Clausthal.

William Frederick Prouty, University, Ala.

Proposed by Eugene A. Smith, H. B. Litchman, Charles F. Rand.

Born, 1879, Putney, Vt. 1903, B. S., Syracuse University. 1904, M. S., Syracuse Univ. 1906, Ph. D., Johns Hopkins University. 1903-04, Instructor of Geology, Syracuse Univ. 1905-06, Asst., Md. Geological Survey. Summer 1906, U. S. Geological Survey Party in Ala. 1906 to present, Chief Asst. Ala. Geological Survey. 1906-11, Associate Professor of Geology and Mineralogy, University of Ala. 1911, Professor of Geology, University of Ala.

Present position: Professor of Geology, Univ. of Ala., also Chief Asst. Ala. Geological Survey.

George K. Reeder, Spokane, Wash.

Proposed by L. K. Armstrong, J. C. Haas, E. P. Spalding.

Born 1887, Kansas City. 1903-07, Spokane High School. 1907-12, State College of Wash., grad. in mining engineering; B. S. degree. 1913, Moyie Gold Mining & Milling Co. 1911-12, Triplex M. & Milling Co., Mont. 1913, Ore sampling crew at Republic, Wash., Water Power Co.; Hazel T. Mining Co., operating in Mont.; Cornucopia Mines Co., Cornucopia, Ore.

Present position: Hazel T. Mining Co., Mont.

Frank Curtis Rork, Sellwood, Ont., Can.

Proposed by (three signatures required).

Born, 1880, Lansing, Mich. 1899, Grad. Lansing High School. 1903, Grad. Mich. Agri. College. 1905, Grad. Mich. College of Mines; degree B. S., C. E. from Mich. Agri. College, E. M. from Mich. College of Mines. 1905-11, Doe Run Lead Co., from surveyor to head of mine. 1911, Dome Mines Co. 1912, Std. S., Porcupine, Ont.

Present position: 1912 to date, Mine Supt., Moose Mt., Ltd., Sellwood, Ont.

Paul Curtis Schrapa, Guayaquil, Ecuador, So. Amer.

Proposed by T. W. Mather, Arthur L. Kelley, Rush W. Hess.

Born, 1886, Detroit, Mich. 1905, Bryant and Stratton Business College, St. Louis, Mo. 1907, Entrance work, So. Dak. School of Mines. 1908-12, Mackay School of Mines (U. N.), Reno, Nev.; B. S. 1908, Nev. Goldfield Reduction Works, Goldfield, Nev.; Combination Fraction Mine, Goldfield, Nev. 1906, Cole Shaft, Superior & Pittsburg Copper Co., Bisbee, Ariz. 1911, Ward Shaft Pumping Asso., Virginia City, Nev. 1912, West End Mining Co., Tonopah, Nev. 1913, Prospecting, Plumas Co., Cal.

Present position: Mine Shift Boss, So. Amer. Dev. Co.

William Joseph Schulze, Virginia, Minn.

Proposed by John B. Arnold, Kirby Thomas, Henry C. Carr.

Born, 1877, Decorah, Iowa. 1881-1894, Public School, Decorah. 1905, Valders Business College. 1896-98, Univ. Iowa. 1899-1900, Drake Univ. 1900, Clerk, Oliver Iron Mining Co., Mountain Iron Mine. 1901, Asst. Mining Captain, Mountain Iron Mine. 1902-04, Supt. Stephens Mine of Oliver Iron Mining Co., Virginia. 1905, Secretary, Tesora Mining Co. 1907, Supt. of Mines of W. H. Yorokey *et al.* in Mesabi Range, Minn.

Present position: Secretary, Tesora Mining Co.

Paschal Green Shook, Birmingham, Ala.

Proposed by George G. Crawford (two additional signatures required).

Born, 1872, Nashville, Tenn. 1882-86, Private School at Tracy City, Tenn. 1887, Univ. of South, Sewanee, Tenn. 1888-90, Winchester Normal School, Winchester, Tenn. 1890-92, Terrill College, Ditchard, Tenn. 1892-93, Southern Iron Co., Chattanooga, Tenn. 1893-98, Chief Clerk to General Manager, Tenn. Coal, Iron & R. R. Co., Birmingham, Ala. 1898-1901, Secy. and Treas. and Asst. General Supt., Alabama Steel & Shipbuilding Co.

Present position: 1901 to date, Shook & Flucher, Brokers and Manufacturers' Agents.

Jay Mark Smith, Pittsburg, Pa.

Proposed by D. M. Armstead, Charles F. Rand (one additional signature required).

Born, 1883, Duluth, Minn. 1902-06, Lafayette College, Easton, Pa.; E. M. Engineer for Oliver Iron Mining Co. 1908-09, Butler Bros., Stripping Contractors, Nashua, Minn. 1912-13, Ingersoll-Rand Co.

Present position: Sales Engineer with Ingersoll-Rand Co.

Edward Morton Spedden, Chewelah, Wash.

Proposed by L. K. Armstrong, J. C. Haas, Charles H. Goodwell.

Born, 1878, Astoria, Ore. High School, Chewelah, Wash. 1893, Sherwin Hydraulic, Idaho. 1901, Buffalo Hump, Idaho. 1902-07, Granby Mines, B. C. 1908, United Copper, Washington. 1910, Elk City, Idaho.

Present position: Supt. Chewelah Copper King Mining Co.

Roger S. Sperry, Waterbury, Conn.

Proposed by David D. Irwin, Louis D. Huntoon, G. M. Colvocoresses.

Born, 1889, Waterbury, Conn. 1910-12, Sheffield Scientific School; Ph. B., E. M. 1912, Cananea Consolidated Copper Co., Experiment work; Inspiration Consolidated Copper Co., Sampling. 1913, New Cornelia Explorations, Ariz., Surveying; Ariz. Copper Co., Surveying.

Present position: Ariz. Copper Co., Engineer on Construction.

Hugh MacGregor Steven, Timmins, Ont., Canada.

Proposed by Reginald E. Hore, P. A. Robbins, Arthur A. Cole.

Born, 1890, Hamilton, Canada. 1899-1905, Highfield School, Hamilton, Can. 1906-7, Upper Canada College, Toronto. 1907-11, School of Practical Science, Faculty of Applied Science, Univ. of Toronto; degree B. A. S. 1909, McKinley, Darragh Co., and Nova Scotia Mine, Cobalt; Assayer, Surveyor, etc. 1910, Welch Mines, Gowganda; Supt. 1911-12, Hollinger Gold Mine, Ltd., Chief Assayer and General Engineering work.

Present position: 1912 to date, Mine Engineer, Canadian Mining Finance Co., Timmins, Ont.

Herbert J. Stiebel, Bingham Canyon, Utah.

Proposed by Burr A. Robinson, R. H. Allen, Charles E. Locke.

Born, 1887, St. Louis, Mo. 1905, Brookline High School. 1909, Mass. Inst. of Tech.; B. S. 1909, Utah Copper Mill, Garfield, Utah; Asst. Engineer, Ohio Copper Mine, Bingham Canyon, Utah. 1910, Engineering squad and sampling, Utah. 1911, Copper Mine, Bingham Canyon, Utah; Asst. to Manager at Sierra Plata. 1913, Mining Co., Villa Escobedo, Parral, Chih., Mexico.

Present position: Sampler, Utah Apex Mine, Bingham Canyon, Utah.

Frederick Edward Stoller, Dillonvale, Ohio.

Proposed by Charles H. Fulton, Z. Jeffries, F. A. Fahrenwald.

Born, 1888, Tuscarawas Co., Ohio. 1893-1905, Grammar and High Schools. 1909, A. B., Western Reserve University. 1911, B. S., Case School of Applied Science. 1911-13, M. A. Hanna & Co., Cleveland, Ohio.

Present position: Mining Engineer, M. A. Hanna & Co.

George Lewis Swarva, Treadwell, Alaska.

Proposed by Milnor Roberts, Joseph Daniels, Henry Landes.

Born, 1888, Seattle, Wash. 1894-1906, Grammar and High Schools, Seattle, Wash. 1906-11, Univ. of Wash., School of Mines; degree B. S. in Mining Engineering. Summer, 1907, Miner, Pittsburg Lead Mining Co., Wallace, Ida. Summers 1908-9, Federal Mining & Smelting Co., Wallace, Ida., Miner. 1911-12, Kennecott Mines, Kennecott, Alaska; Mill Construction and Surveying. 1912, Miner, Alaska Treadwell Gold Mining Co., Treadwell, Alaska.

Present position: Shift Boss, 700 Mine, Alaska Treadwell Gold Mining Co.

Joseph Alexander Taff, San Francisco, Cal.

Proposed by J. C. Branner, C. F. Tolman, Jr., D. M. Folsom.

Born, 1862, Ten Mile, Tenn. 1885-88, Univ. of Ark. 1892-94, Univ. of Texas; B. S. degree. 1888-89, Field Asst., Geological Survey of Ark. 1889-94, Asst. Geologist, Geological Survey of Texas. 1894-1909, Asst. Geologist and Geologist, U. S. Geological Survey. 1909, Geologist, Southern Pacific Company.

Present position; Geologist, Southern Pacific Co.

Frank R. Van Campen, Latouche, Alaska.

Proposed by G. B. Wilson, Charles Simenstad, L. A. Levensaler, S. Birch.

Born, 1882, Olean, N. Y. 1900, Grad. Olean, N. Y., High School. 1906, Mining Course Stanford Univ. 1900, Street Pavement const. in various N. Y. State cities. 1901, Asst. U. S. G. S., Topographic work in N. Y. State; Asst. Foreman Roundhouse, Olean, P. R. R. 1902, Asst. Engineering Dept. P. S. & N. R. R. on construction work Penn. R. R. 1903, Masonry Inspector Eng. Dept. P. S. & N. R. R. 1904, Construction work, Producers Gas Co., Olean. 1905, Asst. Engr. Dept. Tonopah R. R.; Surveyor, Mohawk Alpine Ming. Co., Silver Peak, Nev. 1906, Surveyor, Pittsburgh Silver Peak Ming. Co. 1907, Supt. Const. Ash Meadows Water Co., Rhyolite, Nev. 1908, Timber Boss at Cumberland-Ely Copper Co., Ely, Nev. 1909, Assay Dept. Steptoe Valley Smelting & Mining Co., Ely, Nev.; Supt., West Mining Co., Barth, Nev. 1910-11, Foreman, Beatson Copper Co., Latouche, Alaska.

Present position: 1912 to date, Manager, Beatson Copper Co.

William D. Waltman, Casper, Wyo.

Proposed by Charles W. Comstock, O. R. Whitaker, Thomas S. Harrison.

Born, 1876, Kendallville, Ind. 1883-93, Grade, Grammar and High Schools. 1895-99, Technical education at Colo. School of Mines; degree E. M. 1895-99, Vacations, surveying and mining. 1899-1900, Asst. Engr. Mining work, Cripple Creek and Colo. Springs. 1901-04, Asst. City Engr.; Colo. Springs, Colo. 1905-10, Supervisor and Supt. of Construction, Central and Atlantic Divisions, Panama Canal. 1910-12, Chief Engr., Costilla Estates Development Co., San Acacio, Colo. 1912-13, General Manager, Franco Wyoming Oil Co.; Vice-President, Jumper Californian Gold Mines Co., Casper, Wyo.

Present position: General Manager, Franco Wyoming Oil Co.

Jesse B. Warriner, Lansford, Pa.

Proposed by F. W. Chase, Paul Sterling, A. B. Jessup.

Born, 1883, Montrose, Pa. To 1901, Montrose Public Schools. 1901-05, Penn. State College, course in Mines and Mining; degree B. S. in Mining Engineering. Summers, 1903 and 1904, Engineer Corps, Lehigh Valley Coal Co., Lehigh & W. R. Co., 1905-07, Engineer, Lehigh Valley Coal Co., Wilkes-Barre, Pa. 1907-09, Dist. Engr. Coal Dept., Delaware, Lack. & Western R. R. Co., Scranton, Pa. 1909-11, Mine Inspector, Northwestern Improvement Co., Tacoma, Wash. 1911-12, Supt. of Mines, Denney-Renton Clay & Coal Co., Seattle, Wash. 1911-12, Member Commission of Five for Revision State Mine Laws of Washington. 1912-13, Mining Engineer, the G. B. Markle Co., Jeddo, Pa.

Present position: Chief Engineer, Lehigh Coal & Navigation Co.

Howard G. Washburn, Flat River, Mo.

Proposed by H. A. Guess, A. E. King, C. J. Adami.

Born, 1880, Denver, Colo. 1892-99, Denver Public Schools, West Denver High School. 1899-1904, Colo. School of Mines; E. M. 1904-05, Portland Gold Mining Co., Victor, Colo. 1906-14, Federal Lead Co., Flat River, Mo.

Present position: Superintendent.

Semen George Weinberg, St. Petersburg, Russia.

Proposed by Thomas T. Read, Louis D. Huntoon, A. G. Dwight.

Born, 1872, Rostoff on the Don. 1900, Michigan College of Mines, Houghton, Mich.; B. S. and E. M. 1900, Paul Boeckel Bricket Works, St. Petersburg, Russia. 1905, Tchoudoro Cement Works, Russia. 1910, St. Petersburg City Refuse Destruction; Nicolajeff Water Works.

Present position: International Steam Pump Co., Manager for Russia.

Livingston Wernecke, Juneau, Alaska.

Proposed by H. A. Keller, B. L. Thane, J. R. Whipple.

Born, 1883, Livingston, Mont. 1906, Grad. from Univ. of Washington, Seattle; B. S. Summer, 1903, Rodman and chairman, U. S. Geological Survey. Summer, 1904, Draftsman, Northwest Improvement Co., Roslyn, Wash. (Coal Mine). Summer, 1905, Asst. Mineral Supervisor, State of Wash.; Lewis and Clark Exposition, Portland Coal land examination; Samuel Hill, Seattle. Summer, 1906, Surveyor, G. M. Ashford, Nome, Alaska. 1906-07, Draftsman and constructing engineer, Nevada Consolidated Copper Co., McGill, Nev. 1908-11, Draftsman, Chief draftsman, resident engineer, roadmaster and division engineer, Copper River & Northwestern Ry., Cordova, Alaska. 1912, Examining gold prospects in Black Hills, S. D.; Drilling placer ground and examining gold prospects, Seward, Alaska.

Present position: Constructing engineer, Alaska Gastineau Mining Co., Juneau, Alaska.

Charles Valentine Weston, Dos Cabezas, Ariz.

Proposed by Frank L. Sizer (two additional signatures required).

Born, 1857, Kalamazoo, Mich. Education in the Public Schools of Mich. and private tuition. 1879, Engineering corps Texas Trunk Ry. 1880-83, Miss. Pacific Railway Co., Location and Construction. 1883-85, Engineering dept., Chicago & Northwestern Railway Co., charge of construction. 1886-88, Division Engineer and Engineer in charge of construction Gulf, Colo. & Santa Fe Railway, Galveston, Texas. 1888-1890, Engineer in charge construction of water tunnels and intake cribs under Lake Michigan for water supply city of Chicago. 1890-94, Chief Engineer, charge of construction, West Chicago Street Railway tunnel under Chicago River. 1894-1901, Chief Engineer in complete charge of building Northwestern Elevated Ry., Union Elevated Ry., extensions to Lake St. Elevated Ry., Chicago, Ill. 1901-03, Private practice as Consulting Engineer, Chicago. 1903-11, South Side Elevated Ry. Co., Chicago, Chief Engineer and General Manager and President. 1911 to date, Mascot Copper Co., Ariz., as Director, Vice-president and General Manager.

Present position: General Manager.

William Albert Wolf, Guayaquil, Ecuador, So. Amer.

Proposed by T. W. Mather, Rush M. Hess, A. L. Kelley.

Born, 1882, Winnemucca, Nev. 1899-1903, School of Mines, Univ. of Nev. 1900-02, Miner and Millman during vacation periods. 1903, Hydrographic work, Nevada. 1904, U. S. Reclamation Service, Nevada; Field and office. 1905, U. S. R. S. 1906, Private work, assaying and surveying. 1907-13, Mining and Milling

Present position: Charge of Cyanide plant, S. A. D. Co.

E. G. Woodruff, Washington, D. C.

Proposed by E. W. Parker, M. R. Campbell, D. T. Day.

Born, 1872, Pennsylvania. 1896-1901, Undergraduate work in Univ. of Nebr. 1903-04, Grad. work Univ. of Nebr. 1904-06, Instructor in Mineralogy and Geology, Univ. of Okla. 1906-07, Grad. student, Harvard. 1904-06, Summer employment by the U. S. Geological Survey.

Present position: 1907 to date, Geologist, U. S. Geological Survey.

Elmer Ellsworth Yake, Steelton, Pa.

Proposed by R. V. McKay, F. D. Carney, Charles P. Turner.

Born, 1885, Annville, Pa. 1897-99, Annville High School. 1907-08, Lebanon Valley College, Annville, Pa. 1908-12, Lehigh Univ.; E. M. 1900-02, A. S. Kreider Shoe Co. 1903, Lebanon Valley Iron Co. 1904, The Penn. Steel Co. 1912, Maryland Steel Co. 1913, The Penn. Steel Co., Steelton, Pa.

Present position: In Blast Furnace Dept.

Roberto Yrizar, Catorce, San Luis Potosi, Mexico.

Proposed by Robert Peele, H. S. Munroe, Thomas T. Read.

Born, 1872, Catorce, S. L. P. 1883-89, Student in Spain, B. A. 1890-95, School of Mines of Columbia College, N. Y., degree Mining Engineer. 1895-96, Traveling in France and Spain, visiting copper mines of Montana and silver mines of Cripple Creek and Salt Lake City. 1897-1900, in charge of Patio process Amalgamation at Cedral, S. L. P. 1900-03, In charge of Santa Ana y Anexa mines, Catorce. 1903-06, Mgr. construction work at Ogarrio R. R. Potrero, Catorce, S. L. P.

Present position: 1907 to date, Mgr. Sta. Ana y Anexa mines at Refrigo, S. L. P., and Vice-President of Ogarrio Electric Railway.

Ernest V. Deshayes, Baldy, N. M.

Proposed by C. T. Griswold, J. T. Sparks, L. B. Smith.

Born, 1888, North Castle, N. Y. Public school education, finishing at Central High School, Pueblo, Colo. 1910, Grad. Colo. College School of Mines; B. S. 1910, Employed by the State of Colo. on a commission to investigate the flow of water in the South Fork of the South Platte. 1910-11, Instrument man for the Pueblo-Rocky Ford Land & Irrigation Co. 1911, Employed by the Maxwell Land Grant Co. as Millman, Chemist and Mine Foreman.

Present position: Mine Foreman.

Frederick A. Gowing, Piedmont, Cal.

Proposed by W. R. Hamilton, W. P. Hammon, Newton Cleaveland.

Born, 1881, Oakland, Cal. 1903, Univ. of Cal.; A. B. 1904-06, Examination work, Ariz. 1906-07, Supt. Pocke Mine, Chihuahua, Mex. 1907-08, Engineer, Cal. Dev. Co.; Mine Engineer, Greene Cananea (underground engineering).

Present position: 1908 to date, Examining Engineer, W. P. Hammon.

Alexander K. Hamilton, Chicago, Ill.

Proposed by Robert W. Hunt, George M. Davidson, C. W. Gennet, Jr.

Born, 1873, Johnstown, Pa. Common Schools and High School, Johnstown, Pa. Stevens Institute of Technology; M. E. 1895-1902, Cambria Steel Co., charge of tests of engines, boilers, and plants, then in Drawing Room, Asst. to Chief Draftsman. 1902-05, Lackawanna Steel Co., charge of design of slot and plate mills, later Asst. Chief Engineer and Chief Engineer. 1905-07, Millikin Bros., Inc., General Supt. of Steel Works; had charge of design, construction and operation of plant.

Present position: 1907 to date, Pres. M. H. Treadwell Co. of Ill., Engineers and Contractors, who design and manufacture machinery used in Steel Plants, etc.

Edward Jacob Harrison, Humboldt, Ariz.

Proposed by R. T. Walker, D. J. Evans, G. M. Colvocoresses.

Born, 1874, Ireland. St. Johns School for boys, England. 1900-03, Catholic Univ. of America, Brookland. 1903-04, George Washington Univ., Washington, D. C. Civil Engineering course in both institutions. Passed U. S. Civil Service Examination for Ordnance Draftsman. Ten years as apprentice and journeyman machinist. 1903-06, Various employment as Draftsman and Mechanical Engineer. 1906-11, Smelter and Concentrator Draftsman and Millman, Cananea Cons. Copper Co. 1911-12, Asst. to Cons. Mill Engineer Insp. Copper Co. 1912-13, Repath & McGregor, Draftsman.

Present position: Mill Supt., Consolidated Ariz. Smelting Co.

James Heggie, Hayden, Ariz.

Proposed by A. Eilers, Willard S. Morse, Thomas T. Read.

Born, 1875, Dundee, Scotland. 1892, Grad. from Joliet High School, Joliet, Ill. 1897, Grad. Univ. of Mich.; B. S. 1895, In laboratory Joliet Works of Ill. Steel Co. 1896, In laboratory Western Electric Co., Chicago, Ill. 1897-98, Parke Davis & Co., Mig. Druggists, Detroit, Mich. 1898, Detroit Gas Works. 1899-1905, American S. & R. Co., Pueblo, Colo., and Durango. 1906-08, U. S. Smelting Co., Midvale, Utah. 1908-11, Garfield Smelting Co., Garfield, Utah. 1912-13, Hayden plant, A. S. & R. Co.

Present position: Superintendent.

William Henry Hinn, Hibbing, Minn.

Proposed by A. P. Silliman, A. C. Oberg, Oscar B. Warren.

Born, 1888, Fennimore, Wis. 1904, Fennimore High School. 1910, B. S. (Civil Engineering) Univ. of Wis. 1907, Wis. Geological and Natural History Survey. 1910-11, Oliver Iron Mining Co. 1912, The Shenango Furnace Co.

Present position: Mining Engineer with A. P. Silliman.

Hans Hilbenz, Friemersheim, Germany.

Proposed by A. Eilers, P. A. Mosman, Willard S. Morse.

Born, 1869, Althrehe. 1891, Gymnasium. 1891-94, Hochschulen in Leipzig, Erlangen, Rostock. 1895-96, Stahlwerks-Assistent, Gutehoffnungshütte, Oberhausen. 1899, Stahlwerks-Ass. Gewerkschaft Deutscher Kaiser, Bruckhausen. 1902, Stahl u. Walwerks Chef, Deutsch-Luxemburgische Bergwerks u. Hütten A. G., Differdingen. 1903, Walwerks Chef, Aachener Hütten Verein. 1906, Director, Oberschlesische Eisenbahnbedarf.

Present position: 1906 to date, Mitglied des Directoriums der Fried. Krupp A. G., Essen.

Allan Curtis House, Cleveland, Ohio.

Proposed by H. M. Hanna, Jr., F. B. Richards, L. E. Dunham.

Born, 1886, Marion, Iowa. 1901-02, The Hill School. 1903, Phillips Exeter Academy. 1907, Special student at Amherst. 1906, Oliver Iron Mining Co. 1910 to date, M. A. Hanna & Co., operation of their Iron Ore interests.

Present position: M. A. Hanna & Co. and Secretary of the Wakefield Iron Co.

George Powell Hulst, East Chicago, Ind.

Proposed by J. W. Allen, H. A. Keller, W. S. Harper.

Born, 1877, Columbus, Nebr. 1895-97, So. Dak. School of Mines, special course in chemistry and metallurgy. Supt. International Lead Refining Co., East Chicago, Ind. 1898-1910, Supt. Lead Refinery, American Smelting & Refining Co., Omaha. 1911, Supt. Lead Refinery, American Smelting & Refining Co., Perth Amboy, N. J. 1912, Metallurgical Engineer and Supt. Construction, International Lead Refining Co.

Present position: Superintendent.

Robert Hursh, Denver, Colo.

Proposed by J. A. Van Mater, Russell B. Paul, E. W. Keith.

Born, 1885, W. Somerville, Mass. 1898, Peabody Grammar School, Cambridge, Mass. 1902, Cambridge High School. 1906, Mass. Inst. of Technology; S. B. Mining Engineering course. 1906-07, American Smelting & Refining Co., Monterey, N. L., Mexico. 1907-13, Empire Zinc Co., Monterey.

Present position: In charge interests Empire Zinc Co. in Republic Mexico with headquarters at Denver.

Frederick Atkins Johnston, Prince Bay, N. Y.

Proposed by A. W. Johnston, J. F. Kemp, R. C. Stanley.

Born, 1874, Brooklyn, N. Y. 1893-94, Columbia Univ. School of Mines. 1895-96, Wesleyan University; B. S. 1898 to date, S. S. White Dental Manufacturing Co.

Present position: 1902 to date, Supt. Assay and Metallurgical Division, refining and manufacture of precious metals for dental use.

Frank Joseph Kraemer, Felton, Cuba.

Proposed by Fred C. Wilson, James E. Little, Charles F. Rand.

Born, 1886, Frackville, Pa. 1903, Grad. Frackville High School. 1904, Bucknell Univ. 1904-08, Lehigh Univ.; E. E. 1908-09, Electrical Dept. Bethlehem Steel Co. 1910-11, Mechanical Dept. for Phila. & Reading Coal & Iron Co. 1911-12, Experimental Engineer, Spanish American Iron Co., Felton. 1912-13, Charge of Incline Machines.

Present position: Asst. to Supt. Having charge of all mechanical and electrical machinery on Mayari Division of Spanish American Iron Co.

Ernest William Kohl, Jr., Santiago de Cuba, Cuba.

Proposed by G. W. Pfeiffer, P. O. Persing, Charles F. Rand.

Born, 1884, Philadelphia, Pa. 1889-97, Public Schools of Phila. 1897-1901, Central High School of Phila.; B. S. 1901-02, Private engineering studies. 1902-05, Chairman, Rodman, Levele, Transitman, Inspector, and Draftsman with Phila. & Reading Ry. 1905-06, Draftsman, Inspector and Chief of Party on sewer work and street paving, Borough of Norristown. 1906-09, Penn. Ry. as Draftsman, Transitman and Inspector. 1909 to date, Asst. Engineer, Principal Asst. Engineer and Chief Engineer of the Spanish American Iron Co., Daiquiri, Cuba.

Present position: Chief Engineer Spanish American Iron Co.

Lovell Lawrence, Port Henry, N. Y.

Proposed by R. V. Norris, W. L. Lawrence, I. A. Stearns.

Born, 1887, Scranton, Pa. 1910, E. M., Lehigh Univ. 1910-12, Mining Engineer with Cheever Iron Ore Co., Port Henry, N. Y.

Present position: 1912 to date, Mill Supt., same company.

John Lloyd, Wilkes Barre, Pa.

Proposed by F. M. Chase, Paul Sterling, Charles Enzian.

Born, 1863, North Wales, G. B. 1869-73, Wilkes Barre, Pa., Public Schools. 1873-83, Wilkes Barre Public Schools, when not working in mines; night schools and private instruction. 1883-93, Self instruction and mechanical engineering course, International Correspondence Schools. 1893 to date, Self instruction. 1873-83, Various positions inside anthracite mines, last year as miner. 1883-86, Apprentice and machinist, coal mining machinery. 1886-90, Machinist. Dickson Mfg. Co. & Vulcan Iron Works. 1890-91, Outside Foreman, Stevens Coal Co. 1891-1900, Vulcan Iron Works, journeyman and field engineer. 1900-01, Perfecting drawings and patent of Wyoming steam eliminator. 1901-03, Mechanical Draftsman, Jeansville Iron Works, designing mine pumps. 1903-06, Mechanical Draftsman, Lehigh Valley Coal Co. 1906-13, Equipment Inspector.

Present position: Efficiency Engineer, Lehigh Valley Coal Co.

Frederick R. Lyon, Boston, Mass.

Proposed by W. G. Sharp, W. A. Wilson, C. F. Moore.

Born, 1863, Austria. 1885, Grad. at the German Polytechnic School, Prague, Austria. 1886-93, Engineer on U. P. Ry. 1893-97, Chief Mineral Dept. U. S. Surveyor General's Office, Salt Lake City. 1898-99, Volunteer U. S. Army. 1899-1910, U. S. Smelting, Refining & Mining Co. as Engineer and General Manager of mines and smelter in Cal.

Present position: 1910 to date, Vice President in charge of operations of the U. S. Smelting, Refining & Mining Co.

Ralph N. Marble, Jr., Hibbing, Minn.

Proposed by J. C. Agnew, Oscar B. Warren, A. P. Silliman.

Born, 1879, Harrisville, Mich. 1898, Grad. U. S. Naval Academy. 1905, Grad. Columbia Univ.; E. M. 1905-07, Engineer, Oliver Iron Mining Co., Ishpeming, Mich. 1907-10, Chief Engineer Chemung Copper Co., Tyrone, N. M.

Present position: 1910 to date, Chief Engineer Mahoning Ore & Steel Co., Hibbing, Minn.

Karl Nibecker, Youngstown, Ohio.

Proposed by C. S. Robinson, H. S. Braman, G. A. Reinhardt.

Born, 1886, Sockarosett, R. I. 1907, Grad. Mechanical Engineering Dept. of Univ. of Penn.; B. S. in M. E. 1910, M. E. 1907-09, Instructor in Mechanical Engineering at Univ. of Penn. 1909-10, Experimental engineer with Southwark Foundry & Machine Co., Phila. 1910-13, Pittsburgh representative of Southwark Foundry & Machine Co.

Present position: Steam Engineer, Youngstown Sheet & Tube Co.

Harry Ellsworth Nold, Pocatontas, Alta., Canada.

Proposed by G. H. Morse, R. H. Morris, Frank A. Ray.

Born, 1883, Leetonia, Ohio. 1910, E. M., Ohio State Univ., Columbus, Ohio. 1906-07, Asst. Engineer, Mexican Coal & Coke Co., Las Esperansas. 1910-11, Asst. in Dept. of Mining, Ohio State Univ. 1911-12, Supt., Starr-Hocking Coal Co., Starr, Ohio.

Present position: 1912 to date, Chief Engineer, Jasper Park Collieries, Ltd., Pocatontas, Alta., Can.

Tom Mackellar Owen, Sydney, Australia.

Proposed by J. B. Wilson, E. A. White, H. St. John Somerset.

Born, 1883, Sydney, Aust. Grad. Sydney Univ. Engineering. Three years practical work underground and surface in B. H. Proprietary and B. H. South Blocks, B. H. Junction Mine, Broken Hill.

Present position: Past six years Mill Supt. and Metallurgist at B. H. Junction North, Broken Hill.

Drury McNeill Phillips, Alba, Texas.

Proposed by W. B. Phillips, Charles F. Rand, A. R. Ledoux.

Born, 1887, Chapel Hill, N. C. Univ. of Texas and Univ. of N. Carolina. Grad. from Univ. of N. C. in 1908; B. S. Worked for the Tenn. C. & Ry. Co., Ensley, Ala., in charge of pyrometers. Student apprentice, Allis-Chalmers Co., Chicago. Gas Dept. of the S. W. States Portland Cement Co., Eagle Ford, Texas. 1911-12, Asst. on oil and gas survey of Wichita and Clay counties, conducted by the Bureau of Economic Geology and Technology, Univ. of Texas.

Present position: Mining Engineer for Consumers Lignite Co., Alba, Texas.

Harlow Dow Savage, Ashland, Ky.

Proposed by Banks Hudson, A. F. Plock, S. E. Doak.

Born, 1880, Memphis, Tenn. To 1896, Public Schools. 1896-97, Kenyon Military Academy, Gambier, Ohio. Technical knowledge from practical experience in charge of Company's mines. 1897 to date, Ashland Fire Brick Co.

Present position: Gen. Sales Mgr. and Treas.

Herbert Edgar Schmidt, Hibbing, Minn.

Proposed by J. C. Agnew, Oscar B. Warren, A. P. Silliman.

Born, 1888, Milwaukee, Wis. 1911, Grad. Univ. of Wis.; B. S. in Mining Engineering. 1911-12, Asst. Engineer with Oliver Iron Mining Co., Hibbing, Minn.

Present position: 1912 to date, Asst. Chief Engineer for Mahoning Ore & Steel Co., Hibbing, Minn.

Archie Scott, Humboldt, Ariz.

Proposed by G. M. Colvocoresses, R. T. Walker, D. J. Evans.

Born, 1882, Windsor, Ont., Can. 1897-1902, Troop Polytechnic Institute, Pasadena, Cal. 1903-05, Guanajuatillo Mining Co., mill work and Assaying. 1905-06, Santa Rita Min. Co., Mexico, assayer. 1906-08, Takilina Smelting Co., Takilina, Ore., Blast furnace foreman. 1908-11, Assayer for R. A. Perez, Los Angeles, Cal. 1912-13, Assayer and Chemist, Swansea Consolidated Smelting Co.

Present position: Assayer and Chemist, Consolidated Ariz. Smelting Co.

Robert Alexander Semple, Virginia City, Mont.

Proposed by J. A. Grimes, Reno H. Sales, Paul Billingsley.

Born, 1887, Glasgow, Scotland. 1892-1901, Public and Grammar Schools, Glasgow, Scotland. 1902-03, Evening classes, Glasgow Technical College. 1907-08, College Entrance requirements, Irving School, N. Y. 1908-12, Columbia Univ.; Engineer of Mines. 1901-03, Building construction, Alexander Knox & Robb, Glasgow. 1903-04, Railroad Construction, Grand Trunk Railway, Canada. 1904-07, Railroad Exploration, Location, Construction in N. W. Ontario with the National Transcontinental Railway of Canada, as Topographer, Draftsman, Leveler, Transitman. 1912-13, Mucker, Timberman, Engineering office, Timekeeper, Supply clerk, Mill Sampler, Millman, Solution Man, Mine Sampler, Assayer, Mine Foreman. Companies, Marion Mining Co., Denver; Miami Copper Co., Inspiration Cons. Copper Co., Miami, Ariz.; West End Milling Co., Tonopah, Nev.; Wilkie Smith & Poland Pony, Mont., Easton-Pacific Co., Virginia City.

Present position: Mining Engineer, Easton-Pacific Co., Virginia City, Mont.

Charles Raymond Stahl, Stotesbury, W. Va.

Proposed by W. G. Caperton (two additional signatures required).

Born, 1880, Wilkes Barre, Pa. 1908, B. S. in Electrical Engineering, Penn. State College. 1901-03, Transitman, Levelman, and Topographer with Mobile, New Orleans and Chicago Ry. 1904-08, Summer vacations as transitman with Phila. & Reading Coal & Iron Co., Ashland, Pa. 1906, Transitman for Southern Railway, Birmingham, Ala. 1908-09, Maryland Coal Co., Asst. Engineer on Coal Breaker Construction.

Present position: Chief Engineer, 1909 to date, E. E. White Coal Co., Glen White, W. Va.

Charles S. Thomas, Denver, Colo.

Proposed by Horace V. Winchell, Frank M. Taylor, John W. Finch.

Born, 1849, Darien, Ga. Common School education, and Law Dept. Mich. Univ.; LL. B.

Present position: U. S. Senator from Colorado.

Goodwin M. Trent, Los Angeles, Cal.

Proposed by E. W. Carson, C. M. Eye, C. T. Durell.

Born, 1887, Salt Lake City, Utah. 1905, Fourth year Student. 1906, Belmont School. 1903-04, Assayer, Dairy Farm Mine. 1907, Mines Goldfield, Nev. 1908, Machine foreman, Cal. Mineral Land Co., Cal. 1909, Machinist and Miner, Nev. Sm. & M. Co., Nev. Power House Foreman, Hidden Treasure Gravel Mine, Cal. 1910, Ore Checker, Pioneer M. & L. Co., Nev. 1910, Millman, Mexican Gold & Silver M. Co., Virginia City, Nev. 1911, Engineer and Millman, Melones M. Co., Cal.

Present position: Engineer, L. C. Trent Engineering Co.

Leland Arthur Walker, Rye Valley, Baker Co., Ore.

Proposed by W. M. Dake, Jr., Ernest Gayford, J. M. Callow.

Born, 1887, Ord, Neb. 1893-1902, Grade Schools, Nebr. and Utah. 1902-06, Salt Lake High School. 1907-11, Univ. of Utah. 1912, B. S. and M. E. 1906-07, Warehouse and Time-keeper, Boston Con. Mill, Garfield, Utah. 1907-11, Mining, Idaho and Mich. Utah Co., Silver Lake, Utah. 1910, George F. Roth Mng. Co., Neal, Idaho., Assaying. 1912, Bully Boy Co., Marysvale, Utah, and Leasing at Stockton, Utah. 1913, Rainbow Mine, Rye Valley, Ore., Assaying, Solution man, Battery man, etc.

Present position: Mill Foreman, Rainbow Mill, Rye Valley, Ore.

Arthur Williams, New York City.

Proposed by T. T. Read (two additional signatures required).

Born, 1868, Norfolk, Va. Private and public Schools of Hartford, Conn., and N. Y. City. 1885 to date, The New York Edison Co., Asst. in Chemical Meter Dept., Supt. of Interior Construction, Electrician of the company, Supt. of Third District, Supt. of Underground Dept., General Inspector, General Agent. Commanding officer, New York Volunteer Forces, Mining Harbor of New York during Spanish-American War.

Present position: General Inspector, General Agent, the New York Edison Co. Vice-president, Yonkers Electric Light and Power Co.

Joel H. Watkins, Washington, D. C.

Proposed by Thomas L. Watson, J. S. Grasty, Frank L. Hess.

Born, 1882, Charlotte C. H., Va. 1904-07, Virginia Polytechnic Inst., student in Geology. 1907-09, Univ. of Virginia, special in Geology. 1907-09, Instructor in Geology, Univ. of Va. 1907-10, Asst. on Va. Geological Survey.

Present position: 1911 to date, Geologist Land and Industrial Dept. Southern Ry., Washington, D. C.

Frederick Abbott Weymouth, Sparrows Point, Md.

Proposed by J. H. Hall, Quincy Bent, F. W. Wood.

Born, 1884, Lowell, Mass. 1902-06, Mining and Metallurgy course at Lawrence Scientific School, Harvard University. 1898-1902, Cambridge Latin School. 1906, Practical Experience in rail mill, Lackawanna Steel Co. 1907-09, Metallurgical work at Maryland Steel Co.

Present position: 1909 to date, Engineer of Tests, Maryland Steel Co.

Henry Frederic Raster, El Paso, Texas.

Proposed by C. A. Bohn, R. A. Mosman, J. J. Ormsbee.

Born, 1881, Sewanee, Tenn. 1902, B. A., Univ. of Tenn. 1903, Post Grad. work along chemical lines. 1902, Asst. in field work U. S. Bureau of Forestry. 1903, Assayer for Barranca Copper Co., Chihuahua, Mexico. 1904 to date, El Paso Smelter.

Present position: Asst. Supt.

Ernest Lichtenberg, London, E. C., England.

Proposed by T. A. Rickard, Horace G. Nichols, Edgar Rickard.

Born, 1868, Liverpool, England. 1884-88, Royal School of Mines. 1887-92, Dowlais Iron & Coal Co. and Tillery Colliery, S. Wales, W. Va., Pa. 1892-99, Manager's certificate; Colliery Manager, Tillery Colliery. 1900-02, Mgr. Laubuan Coal Co., Borneo. 1902, Member of the Inst. Mining and Metallurgy. 1903, West Africa Gold. 1904, General Manager, Bibiani Gold Fields. 1905-08, London office, Cons. Engr. to several W. African Gold Mines. 1908, China, Coal; Ceylon, Plumbago. 1909-13, Canada several times, Dalmatia, France, Tunis.

Present position: Consulting Mining Engineer.

H. S. Matthews, Seattle, Wash.

Proposed by F. A. Hill, I. F. Laucks, C. M. Lewis.

Born, 1868, St. Louis Co., Mo. Kirkwood High School. 1899, Leffer Graves Coal & Ry. Co. 1902, General Manager, Graves Shale Paving Brick Co. 1910, General Manager, and Vice-Prest., Alabama Cons. Coal & Iron Co.

Present position, 1912 to date, President, Alabama Cons. Coal & Iron Co.

Associates

William Fayette Bartholomew, Boston, Mass.

Proposed by Louis Ross, E. N. Skinner, A. H. Rogers.

Born, 1871, Jersey City. N. Y. Public Schools. For 18 years associated with Boston News Bureau, last 4 years Editor. 1910, Member Thompson Tonbe Co., Bankers and Brokers, N. Y. and Boston. For past 15 years have made almost annual trips to Copper Mines of U. S., Canada, and Mexico and have devoted special attention to Mining Securities.

Present position: As above.

William Barber Shaffer, Nazareth, Pa.

Proposed by Joseph W. Richards, John Greenall, N. N. Godshall.

Born, 1851, Breinigsville, Pa., Public Schools. 1878-92, Mining Iron Ores in Pa. and Lead and Zinc Ores in Mo. 1892 to date, mostly engaged in the development of Cement property and building cement mills.

Present position: Vice-Prest., Brazilian Land, Lumber & Improvement Co.

Martin A. Roudabush, Osterburg, Pa.

Proposed by E. W. Parker, George O. Smith, Robert H. Chapman.

Born, 1885, St. Clairsville, Pa. 1901-05, Scientific Course, Central State Normal School, Lock Haven, Pa.; B. E. 1905-07, Studied Geology and Civil Engineering. 1906-10, Engaged in land Surveying. 1910-13, Topographic Aid, U. S. Geological Survey. 1913, mapping Coal measures, etc., in W. Va.

Present position: Junior Topographer, U. S. Geological Survey.

Junior Members

Arthur Spencer Callen, So. Bethlehem, Pa.

Proposed by Joseph W. Richards, Benjamin L. Miller, H. Eckfeldt.

Born, 1891, Bethlehem, Pa. 1905-09, Pottstown High School. 1909-10, Ursinus College. Summer, 1912, Pencoyd Iron & Steel Co. Summer, 1910, Champion Silk Co., Pottstown, Pa. Summer, 1909, Pottstown Machine Co. Summer 1907, McClintock-Marshall Co.

Present position: Student at Lehigh University.

Robert John Anderson, Cleveland, Ohio.

Proposed by J. B. Read, Frank R. Van Horn, C. H. Fulton.

Born, 1892, Cleveland, Ohio. 1910-14, Metallurgical Dept. at the Case School of Applied Science, Cleveland. Summers 1911-12, J. E. Christian & Co., Building Contractors, Cleveland. Summer 1913, Chemist, General Chemical Co. National Works, Wilton, Ohio.

Present position: Student at the Case School of Applied Science.

Raymond Joseph Protzeller, N. Catasauqua, Pa.

Proposed by J. W. Richards, Howard Eckfeldt, Henry S. Drinker.

Born, 1892, Hokendauqua, Pa. Public School. 1906-09, Catasauqua High School. 1909-10, Bethlehem Preparatory School. 1910-14, Mining Engineering Course at Lehigh Univ.

Present position: Student at Lehigh University.

T. Watson Downs, Steelton, Pa.

Proposed by Joseph W. Richards, Benjamin L. Miller, H. Eckfeldt.

Born, 1891, Steelton, Pa. 1905-09, Steelton High School. 1909-10, Bethlehem Prep. School. Six months Penn. Steel Co.

Present position: Student at Lehigh University.

Douglas Macdonald Dunbar, So. Bethlehem, Pa.

Proposed by Joseph W. Richards, Benjamin L. Miller, H. Eckfeldt.

Born, 1890, New York City.

Present position: Student at Lehigh University.

Charles W. Francis, Bethlehem, Pa.

Proposed by Joseph W. Richards, Benjamin L. Miller, H. Eckfeldt.

Born, 1891, Chester, Pa. Four Summer vacations in Street Railway Drafting Room of Penn. Steel Co., Steelton, Pa. Feb. to June, 1913, Practical Blast Furnace Work at Maryland Steel Co., Sparrows Point, Md.

Present position: Student at Lehigh University.

Joseph Kalbach Goundie, Allentown, Pa.

Proposed by Joseph W. Richards, H. Eckfeldt, H. S. Drinker.

Born, 1889, Lebanon, Pa. 1911-12, Engineering Dept., Central Railroad of New Jersey.

Present position: Student at Lehigh University for degree of Engineer of Mines.

Herbert W. Graham, Johnstown, Pa.

Proposed by Joseph W. Richards, H. Eckfeldt, H. S. Drinker.

Born, 1891, Johnstown, Pa.

Present position: Student at Lehigh University for degree of Electrometallurgist.

Richard Dudley Jordon, So. Bethlehem, Pa.

Proposed by Joseph W. Richards, Benjamin L. Miller, H. Eckfeldt.

Born, 1891, New York City.

Present position: Student at Lehigh University in Electrometallurgy.

Walter B. Krause, So. Bethlehem, Pa.

Proposed by Joseph W. Richards, Benjamin L. Miller, H. Eckfeldt.

Born, 1890, Lebanon, Pa.

Present position: Student at Lehigh University, Chemical Engineering.

Charles E. Lewall, Jr., Catasauqua, Pa.

Proposed by Joseph W. Richards, H. Eckfeldt, H. S. Drinker.

Born, 1891, Catasauqua, Pa.

Present position: Student at Lehigh University for degree of Mining Engineer.

Verner Thatcher Lawshe, Bethlehem, Pa.

Proposed by Joseph W. Richards, H. Eckfeldt, Benjamin L. Miller.

Born, 1891, Newark, N. J.

Present position: Student in Chemical Engineering, Lehigh University.

Harold Edwin Lenker, Bethlehem, Pa.

Proposed by Joseph W. Richards, Benjamin L. Miller, H. Eckfeldt.

Born, 1889, Schuylkill Haven, Pa.

Present position: Student in Mining Engineering in Lehigh Univ.

John Orth Liebig, So. Bethlehem, Pa.

Proposed by Joseph W. Richards, H. Eckfeldt, H. S. Drinker.

Born, 1890, Sparrows Point, Md. 1898-1904, Sparrows Point Public School, including course in Manual Training. 1904-07, Marstons Univ. School for Boys, Baltimore. 1910, Bethlehem Prep. School, Bethlehem, Pa. 1907-10, Employed as Asst. Chemist in the laboratories of the Maryland Steel Co. 1911-12, Summers, in the same laboratories. 1913, Helper at different times during the summer at the Open Hearth Steel Dept., Maryland Steel Co., Sparrows Point, Md.

Present position: Student at Lehigh University.

James Scott Long, So. Bethlehem, Pa.

Proposed by Joseph W. Richards, Benjamin L. Miller, H. Eckfeldt.

Born, 1892, York, Pa.

Present position: Student at Lehigh University in Chemical Engineering.

Miles Henderson Merwin, So. Bethlehem, Pa.

Proposed by Joseph W. Richards, H. Eckfeldt, H. S. Drinker.

Born, 1892, Pittsburg, Pa.

Present position: Senior class of Metallurgical Engineering, Lehigh University.

Robert E. Mickel, So. Bethlehem, Pa.

Proposed by Joseph W. Richards, H. Eckfeldt, H. S. Drinker.

Born, 1891, Trenton, N. J.

Present position: Student at Lehigh University, for degree of Mining Engineer.

Arthur Newell, Madison, Wis.

Proposed by Edwin C. Holden, A. N. Winchell, J. C. Scoles.

Born 1892, Ashland, Mont. 1897-1905, Grade schools, Ashland, Mont., and Lemon Grove, Cal. 1905-09, Custer County High School, Miles City, Mont. 1909-13, Course in Mining at the Univ. of Wis., summer trip of inspection to New Mexico and Arizona and work at Bisbee. 1912-13, Asst. to C. B. Taber, Irrigation Engineer, Forsyth, Mont.

Present position: Junior at University of Wisconsin.

Edward Beisel Snyder, So. Bethlehem, Pa.

Proposed by Joseph W. Richard, Benjamin L. Miller, H. Eckfeldt.

Born, 1890, Hazelton.

Present position: Student in Mining Engineering, Lehigh University.

Walter Fook Chong Wong, San Francisco, Cal.

Proposed by S. B. Christy, W. S. Morley, E. B. Durham.

Born, 1885, Canton, China. Grad. University of Cal.

Present position: Visiting mines.

Charles Erb Wuensch, Golden, Colo.

Proposed by F. W. Traphagen, Harry J. Wolf, W. R. Chedsey.

Born 1892, Newark, N. J. 1898-1906, Grade Schools of Newark. 1910, Grad. Baringer High School, Newark; started Colo. School of Mines. 1909, Goeller Iron Works, Newark. 1911, Wellington Mine, Breckenridge, Colo. 1913, Colo. State Geological and Topographical Survey, Golden, Colo.

Present position: Senior Student, Colo. School of Mines.

Change of Status—Associate to Members

Ellsworth Maltby Shipp, New York City.

Judd Stewart, 165 Broadway, New York, N. Y.

CHANGES OF ADDRESS OF MEMBERS

The following changes of address of members have been received at the Secretary's office during the month of December, 1913. This list, together with the lists published in *Bulletin* Nos. 76 to 84, April to December, 1913, and the foregoing list of new members, therefore, supplements the annual list of members corrected to Mar. 1, 1913, and brings it up to the date of Jan. 1, 1914.

- ALLEN, ROY H. 64 North 9th St., Newark, N. J.
 ANDERSON, J. K. Chief Engineer, Public Service Commission, Charleston, W. Va.
 ASTLEY, J. W. 15A Manning Arcade, 24 King Street West, Toronto, Canada.
 BATESON, C. E. W. 5th Street, Garden City, N. Y.
 BAGGALY, RALPH. 1291 Shady Ave., E. E., Pittsburgh, Pa.
 BEDDALL, THOMAS H. The Burnwell Coal & Coke Co., Sprigg, Mingo Co., W. Va.
 BILLIN, CHARLES E. c/o Alexander Bradley, 306 W. 82d St., New York, N. Y.
 BOWRON, WILLIAM M. 104 Thomas St., North Chattanooga, Tenn.
 BOYD, HORACE. 21 South Linden St., Bethlehem, Pa.
 BRADLEY, O. U. c/o The United States Indian Agency, Muskogee, Okla.
 BRANDIS, JUAN F. Box 1245, Station K, San Francisco, Cal.
 BROOKS, JOHN M., JR. c/o Aguacate Mines, San Mateo, Costa Rica, C. A.
 BUCHANAN, J. R. P. O. Box 460, Pasadena, Cal.
 BURLEY, C. R., Min. Engr. 6232 34th Ave., N. E., Seattle, Wash.
 CALDWELL, WM. A. 2 Herriet St., Pollokshields, Glasgow, Scotland.
 CAMPHIUS, GEORGE A. Room 614, Mills Bldg., El Paso, Texas.
 CHAMBOST, P. J. E. E., Zarumca Mining Corp'n, Ltd., Casilla Correo No. 642,
 Guayaquil, Ecuador, South America.
 COHEN, MAXWELL B. Miami, Ariz.
 CROMWELL, ROBERT H. 225 Quincy St., Brooklyn, N. Y.
 COPELAND, DURWARD, Metallurgist, Compania Estanifera de Llalagua, Llalagua,
 Bolivia, South America.
 EDWARDS, WILLIAM S. 2690 Colby St., Oakland, Cal.
 EMMEL, RUDOLPH. 930 W. Copper St., Butte, Mont.
 EMMONS, CAROLUS D. Cor. Patterson & East 11th Sts., Eugene, Ore.
 ESELEMAN, S. K., JR. c/o Dixon, 73 Dana St., Cambridge, Mass.
 FIES, MILTON H. Sipsey, Ala.
 FRANK, EMIL A. 3852 No. Monticello Ave., Chicago, Ill.
 FULTON, CHESTER A., Mining Engineer, 798 North Broadway, Yonkers, N. Y.
 GAHL, RUDOLF. c/o Inspiration Cons. Copper Co., Miami, Ariz.
 GATHMANN, EMIL. 904-6 Garrett Bldg., Baltimore, Md.
 GINDER, WILLIAM H. H. Schuylk Haven, Pa.
 GRUNSKY, C. E., JR., American Engineering Corporation, 57 Post St.,
 San Francisco, Cal.
 GUESS, HARRY A., c/o American Smelting & Refining Co., 165 Broadway,
 New York, N. Y.
 HACKWOOD, ARTHUR W. 1135 W. Park St., Butte, Mont.
 HART, PHILIP E., Resident Engineer, Dorada Railway, Ropeway Extension, Ltd.,
 Honda, Colombia, South America.
 HART, VERNE A. Box 1003, Salt Lake City, Utah.
 HAWKHURST, ROBERT JR., c/o International Banking Corporation, Mills Bldg.,
 San Francisco, Cal.
 HENDERSON, H. P. 66 Broadway, New York, N. Y.
 HIBBERT, ERNEST, British America Nickel Corporation, Ltd., Nickelson, via Sudbury,
 Ont., Canada.
 HINRICHSSEN, HENRY T. Calle Colo Colo 646, Concepcion, Chili, South America.
 HOLLAND, L. F. S. 601 H. W. Hellman Bldg., Los Angeles, Cal.
 JAKUES, W. H. 142 Beacon St., Boston, Mass.
 JENNEY, WALTER P. 1727 P St., N. W., Washington, D. C.
 JONES, FAYETTE A., Prest., New Mexico State School of Mines, Socorro, New Mexico.
 JONES, H. EWER, Parliament Mansions, Victoria St., London, S. W., England.
 KENT, WILLIAM. 120 W. 32d St., New York, N. Y.
 KITSON, HOWARD W. British Columbia Copper Co., Princeton, B. C., Canada.
 LEACH, ROBERT H. 8 Brook St., Wellesey, Mass.
 LEFEVRE, H. F. c/o John B. Pruyn, 2 Rector St., New York, N. Y.
 L'ENGLE, E. FLEMING. Chapel House, 54 New Broad St., London, E. C., England.
 LEONARD, HARRY R. 1729 North 6th St., Harrisburg, Pa.
 LINCK, FREDERICK W. "Roydene," The Drive, Sidcup, Kent, England.
 LIVERMORE, THOMAS L., JR. 25 Madison Ave., New York, N. Y.
 LONGAN, WALKER B. Box 955, Nowata, Okla.
 LOW, V. F. STANLEY. The Lloyd Copper Co., Burrage, N. S. W., Australia.
 McDONALD, J. A. Cambria Steel Co., Johnstown, Pa.
 McLINTOCK, ARCHIBALD. 41 Cambridge Place, Brooklyn, N. Y.
 MAGNUSON, MARK G. 1909 Rondo St., Merriam Park, Minn.
 MARSHALL, S. M. 408 Tioga St., Johnstown, Pa.
 MENTZEL, CHARLES. 29 Broadway, New York, N. Y.

MOORE, REDICK R.	Balaklala Copper Co., Coram, Cal.
MORLEY, FREDERICK H.	2616 Channing Way, Berkeley, Cal.
OSBERG, ANTON C.	1518 Jefferson St., Duluth, Minn.
PLOCK, ALBERT F.	818 Park Bldg., Pittsburg, Pa.
PLUMB, C. H.	Butte & Superior Copper Co., Butte, Mont.
REYNOLDS, H. D. G.	Copper Queen Cons. Min. Co., Bisbee, Ariz.
RICE, E. ROCHE	Genl. Mgr., The Efficiency Engineering Co., Bisbee, Ariz.
RONE, LLOYD A.	Apartado 333, Torreon, Coah., Mexico.
SESSINGHAUS, GUSTAVUS	5136 Von Versen Ave., St. Louis, Mo.
SCHLERETH, C. Q.	911 Mariposa St., Denver, Colo.
SHAMEL, C. H.	535 Black Ave., Springfield, Ill.
SHAW, JOSEPH S., Mining Engineer	207 W. 8th St., Fort Worth, Texas.
SIEBERT, FRED J., Min. Engr., Consulting Engineer	Nevada Hills Mining Co., Buckhorn Mines Co., Reno, Nev.
SIEDLER, GEORGE J.	Vice-Prest., The Eynon-Evans Mfg. Co., Philadelphia, Pa.
SLATER, JOHN L., JR.	1064 Filbert St., San Francisco, Cal.
SMITH, ALEXANDER H.	Hermant Bldg., Toronto, Ont., Canada.
SMITH, H. DEWITT	722 Asylum Ave., Hartford, Conn.
SPROAT, A. D.	221 Richmond Ave., San Antonio, Texas.
STOUT, EDMUND DE	11 Rue de l'Hotel de Ville, Geneva, Switzerland.
STUBBS, GEORGE W.	Mining Engineer, 1225 Nicholas Bldg., Toledo, O.
TALCOTT, MORRIS G.	Talcottville, Conn.
TAYLOR, HENRY B.	Lisle, Cass Co., Mo.
THACHER, W. A.	432 W. Locust St., Lodi, Cal.
THOMAS, GEORGE S.	2509 Pioneer Road, Evanston, Ill.
TURNER, NATHANIEL P.	302 S. Washington Ave., Marshall, Texas.
TUTTLE, ARTHUR L.	c/o The Jimulco Min. Co., San Antonio, Texas.
VAN LAW, CHARLES W.	Room 400, 55 Congress St., Boston, Mass.
WALKER, W. LESTER	979 Sutter St., San Francisco, Cal.
WHEELWRIGHT, O. W.	604 E. Gorham St., Madison, Wis.
WILLIAMS, FRED T., Vernon Apts. No. 2, 5th East & 3d South	Salt Lake City, Utah.
WILDING, JAMES, JR., Metallurgist, Minerals Separation Co.	Merchants Exchange Bldg., San Francisco, Cal.

ADDRESSES OF MEMBERS AND ASSOCIATES WANTED

Name.	Last Address of Record, from which Mail has been Returned.
Grill, Charles H.,	Keddie, Cal.
Grove, Independence,	Ampiro Mining Co., Etzatlan, Jal., Mexico.
Hyslop, James E.,	Apartado 48, Parral, Chih., Mexico.
Johnson, Alexander T.,	Yellow Pine Mining Co., Good Springs, Nev.
Keller, Cornelius H.,	Apartado 134, Parral, Chih., Mexico.
Lancaster, Henry M.,	Cœur d'Alene, Idaho.
Lehmer, Frank W.,	Cia Minera Zapoteca, Ocotlan, Oax., Mexico.
Potter, Charles F.,	First National Bldg., San Francisco, Cal.
Schroder, Harold,	Eng. & Aust. Cop. Co., Wasatah, Tasmania.
Watters, Daniel M.,	2557 11th Ave. W., Seattle, Wash.

NECROLOGY

The deaths of the following members were reported to the Secretary's office during the month of December, 1913:

Date of Election.	Name.	Date of Decease.
1897	*Leckie, Robert G.	November 5, 1913.
1900	**Wilson, Richard	May 27, 1913.

*Member.

**Life Member.

STANDING COMMITTEES

*Executive*CHARLES F. RAND, *Chairman.*JAMES F. KEMP,
ALBERT R. LEDOUX,JOSEPH W. RICHARDS,
BENJAMIN B. THAYER.*Membership*BENJAMIN B. THAYER, *Chairman.*KARL EILERS,
JOHN D. IRVING,JOHN H. JANEWAY, JR.,
HERMAN A. PROSSER.*Finance*EDWARD L. YOUNG, *Chairman.*

KARL EILERS,

JAMES GAYLEY.

*Library*JAMES F. KEMP, *Chairman.*¹JOHN HAYS HAMMOND,²
ALEX. C. HUMPHREYS,⁴E. GYBBON SPILSBURY,³
BRADLEY STOUGHTON.*Papers and Publications*BRADLEY STOUGHTON, Ch.
PHILIP ARGALL,
LEONARD S. AUSTIN,
JOHN BIRKINBINE,
WILLIAM H. BLAUVELT,
JOHN C. BRANNER,
DAVID W. BRUNTON,
GELASIO CAETANI,
WILLIAM CAMPBELL,
ALBERT E. CARLTON,
ALLAN JAY CLARK,
NATHANIEL H. EMMONS,
JOHN W. FINCH,
CHARLES H. FULTON,
JAMES GAYLEY,
CHARLES W. GOODALE,C. WILLARD HAYES,
HEINRICH O. HOFMAN,
HENRY M. HOWE,
LOUIS D. HUNTOON,
WILLIAM KELLY,
JAMES F. KEMP,
CHARLES KIRCHHOFF,
CHARLES K. LEITH,
ANTHONY F. LUCAS,
RICHARD MOLDENKE,
SEELEY W. MUDD,
HENRY S. MUNROE,
R. V. NORRIS,
EDWARD W. PARKER,
EDWARD D. PETERS,
ROSSITER W. RAYMOND,JOSEPH W. RICHARDS,
ROBERT H. RICHARDS,
HEINRICH RIES,
E. F. ROEBER,
RENO H. SALES,
ALBERT SAUVEUR,
CHARLES H. SHAMEL,
HENRY L. SMYTH,
GEORGE C. STONE,
RALPH H. SWEETSER,
FELIX A. VOGEL,
ARTHUR L. WALKER,
ROLLA B. WATSON,
HORACE V. WINCHELL.

COMMITTEE ON INCREASE OF MEMBERSHIP

ADOLPHE E. BORIE, *Chairman.*THOMAS T. READ, *Secretary*, Woolworth Bldg., New York, N. Y.*Vice-Chairmen*JOHN H. ALLEN,
RICHARD M. ATWATER, JR.,
GEORGE D. BARRON,
A. CHESTER BEATTY,
J. PARKE CHANNING,GEORGE M. COLVOCORESSES,
ROBERT PEELE,
CHARLES P. PERIN,
JOSEPH A. VAN MATER,
ARTHUR L. WALKER.D. C. BARD,
W. DE L. BENEDICT,
JOHN C. BRANNER,
PALMER CARTER,
ALLAN JAY CLARK,
C. R. CORNING,
F. CRABTREE,
GEORGE G. CRAWFORD,
O. C. DAVIDSON,
E. V. D'INVILLIERS,
JAMES S. DOUGLAS,
WALTER DOUGLAS,
HOWARD N. EAVENSON,
HOWARD ECKFELDT,
R. C. GEMMELL,F. LOUIS GRAMMER,
ERNEST A. HERSAM,
EDWIN C. HOLDEN,
WILLIAM L. HONNOLD,
WALTER E. HOPPER,
REGINALD E. HORE,
TEDASHIRO INOUE,
C. COLCOCK JONES,
EUGENE P. KENNEDY,
CHESTER F. LEE,
RICHARD S. McCAFFERY,
JAMES F. McCLELLAND,
MILTON H. McLEAN,
PHILIP N. MOORE,T. H. O'BRIEN,
JAMES J. ORMSBEE,
EDWARD W. PARKER,
JOHN B. PORTER,
F. DANVERS POWER,
R. M. RAYMOND,
CHARLES RHODES,
ROBERT H. RICHARDS,
LEROY SALSICH,
HENRY LLOYD SMYTH,
F. W. TRAPHAGEN,
ELTON W. WALKER,
CHO YANG,
MORRISON B. YUNG.¹ Until Feb., 1914. ² Until Feb., 1915. ³ Until Feb., 1916. ⁴ Until Feb., 1917.

TECHNICAL COMMITTEES

*Iron and Steel*ALBERT SAUVEUR, *Chairman.*A. A. STEVENSON, *Vice-Chairman.*HERBERT M. BOYLSTON, *Secretary*, Abbot Bldg., Harvard Sq., Cambridge, Mass.

JOHN BIRKINBINE,	WILLIAM KELLY,	FELIX A. VOGEL,
WILLIAM H. BLAUVELT,	CHARLES KIRCHHOFF,	LEONARD WALDO,
JAMES GAYLEY,	RICHARD MOLDENKE,	WILLIAM R. WALKER,
HENRY D. HIBBARD,	JOSEPH W. RICHARDS,	WILLIAM R. WEBSTER
HENRY M. HOWE,	C. F. W. RYS,	FREDERICK W. WOOD.
ROBERT W. HUNT,	E. GYBBON SPILSBURY,	
J. E. JOHNSON, Jr.,	J. S. UNGER,	

*Precious and Base Metals*CHARLES W. GOODALE, *Chairman.*L. D. RICKETTS, *Vice-Chairman.*DARSIE C. BARD, *Secretary*, Montana State School of Mines, Butte, Mont.

LEONARD S. AUSTIN,	THOMAS J. GRIER,	ALBERT F. SCHNEIDER,
DAVID W. BRUNTON,	HENNEN JENNINGS,	GEORGE C. STONE,
THEO. B. COMSTOCK,	EDMUND B. KIRBY,	BENJAMIN B. THAYER.
STANLEY A. EASTON,	CHARLES W. MERRILL,	
SAMUEL S. FOWLER,	WILLET G. MILLER,	

*Mining Geology*JAMES F. KEMP, *Chairman.*JOHN W. FINCH, *Vice-Chairman.*R. A. F. PENROSE, Jr., *Vice-Chairman.*L. C. GRATON, *Secretary*, Harvard Geological Museum, Cambridge, Mass.

RALPH ARNOLD,	ALFRED C. LANE,	HEINRICH RIES,
H. FOSTER BAIN,	CHARLES K. LEITH,	RENO H. SALES,
JOHN M. BOUTWELL,	R. V. NORRIS,	WILLIAM G. SHARP,
H. A. BUEHLER,	EZEQUIEL ORDONEZ,	CHARLES H. SMYTH, Jr.,
WILLIAM H. EMMONS,	WILLIAM B. PHILLIPS,	HENRY L. SMYTH,
F. LYNWOOD GARRISON,	JOSEPH H. PRATT,	JOSIAH E. SPURR.
HENRY LANDES,		

*Mining Methods*DAVID W. BRUNTON, *Chairman.*H. C. HOOVER, *Vice-Chairman.*F. W. DENTON, *Vice-Chairman.*J. F. McCLELLAND, *Secretary*, Drawer C, Yale Station, New Haven, Conn.

TRUMAN H. ALDRICH,	J. R. FINLAY,	H. S. MUNROE,
R. B. BRINSMADE,	R. C. GEMMELL,	W. J. OLCOTT,
DOUGLAS BUNTING,	JOHN GILLIE,	JOHN B. PORTER,
LOUIS S. CATES,	HARRY A. GUESS,	MILNOR ROBERTS,
CHARLES CATLETT,	THOMAS J. GRIER,	OSCAR ROHN,
R. M. CATLIN,	JOSEPH A. HOLMES,	W. L. SAUNDERS,
J. PARKE CHANNING,	WILLIAM L. HONNOLD,	H. L. SMYTH,
CHARLES A. CHASE,	JAMES E. JOPLING,	ARTHUR THACHER,
S. B. CHRISTY,	ROBERT A. KINZIE,	B. W. VALLAT,
F. W. DENTON,	C. B. LAKENAN,	SAMUEL D. WARRINER,
E. V. D'INVILLIERS,	THOMAS H. LEGGETT,	GEORGE WEIR,
STANLEY A. EASTON,	JAMES MAC NAUGHTON,	BULKLEY WELLS.
	SEELEY W. MUDD,	

*Non-Metallic Minerals*HEINRICH RIES, *Chairman.*GEORGE F. KUNZ, *Vice-Chairman.*EDWARD W. PARKER, *Vice-Chairman.*J. C. BRANNER, *Vice-Chairman.*H. J. SEAMAN, *Vice-Chairman.*CHARLES P. BERKEY, *Secretary*, Columbia University, New York, N. Y.

S. W. BEYER,	C. COLCOCK JONES,	W. C. PHALEN,
H. A. BUEHLER,	J. K. McLANAHAN, Jr.,	W. B. PHILLIPS,
R. D. GEORGE,	C. G. MEMMINGER,	J. H. PRATT,
F. L. HESS,	BENJAMIN L. MILLER,	KENNETH SEAVER,
F. R. HEWITT,	WILLET G. MILLER,	T. L. WATSON,
F. C. HOOPER,	J. D. PENNOCK,	

COMMITTEE ON JUNIOR MEMBERS AND AFFILIATED STUDENT SOCIETIES

HARRY H. STOEK, *Chairman*.

Vice-Chairmen

CHARLES H. FULTON,
FREDERICK W. SPERR,
GEORGE J. YOUNG,

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DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the New York meeting, February, 1914, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Apr. 1, 1914. Any discussion offered thereafter should preferably be in the form of a new paper.

The Influence on Quality of Cast Iron Exerted by Oxygen, Nitrogen, and Some Other Elements

BY J. E. JOHNSON, JR., NEW YORK, N. Y.

(New York Meeting, February, 1914.)

At the Cleveland meeting of the Institute in October, 1912, I had the honor to present a paper outlining the conditions surrounding the charcoal iron industry, and giving some of the results of an investigation started about three years ago for the purpose of determining the reason for the poor reputation of the Lake Superior charcoal irons as compared with the Southern and Eastern irons.

In that paper I explained the effect of high carbon on quality, and tried to make clear that that paper was a preliminary one, as we felt convinced that we should eventually discover other factors affecting quality.

The progress of the investigation has brought out facts that seem to us of the utmost importance practically and theoretically, and the purpose of the present paper is to present these facts with the proofs which seem to us to establish them.

The closing year of the nineteenth century saw the publication of the first definite and connected statement of the relationship between the cast irons and the steels.¹ The metallurgical world was ready to accept the fundamental unity of these two series, acceptance being greatly hastened by Professor Howe's classic paper, *The Constitution of Cast Iron*, presented at the Richmond meeting of the Institute, February, 1901.

But the doctrine of chemical control of the quality of pig iron met some obstacles, small but exceedingly difficult of removal. The old

¹ See article, entitled *The Chemistry and Physics of Cast-Iron Briefly Considered*, by J. E. Johnson, Jr., published in the *American Machinist* of Apr. 5 and 12, 1900. In this article the continuity of the cast iron-steel series was set forth at some length and the relationships between soft cast iron on one side and soft steel on the other to white iron as the connecting link, were pointed out in detail, also the mechanical effect of the graphite in reducing the strength of the matrix, and many other matters now perfectly familiar to all.

school of metallurgists, who knew but little chemistry, had always insisted that there were fundamental differences in quality which were not revealed by analysis. The more ardent advocates of the newer theory of chemical control ridiculed this view. Those whose position forced them to look for the facts from whatever source derived came gradually to believe that while the theory of chemical control was in a broad way correct, there were certain facts which this theory did not cover, and that the old-school metallurgists, while wrong in many of their notions, were undoubtedly right as to this.

This view now seems to prevail among those best informed on the subject, and I shall not reiterate here the profusion of hard facts confirming it, which any one may find for himself who will leave the beaten track of foundry work and investigate those by-paths in which special qualities of product are made.

In our search for the explanation for these discrepancies, there seemed, after the most careful consideration, to be two facts which might be taken as established:

1. That certain irons possessed a quality as they came from the furnace which was preserved on remelting, and which reappeared in castings of which these irons formed an important ingredient.

2. That the rarer elements, such as nickel, cobalt, chromium, titanium, vanadium, and the like, while not absent from the point of view of ultimate analysis, were in such small quantity and varied in ways so entirely independent of the quality of the iron that the explanation could not be attributed to them.

In spite of the certainty in our own minds regarding conclusion 1, and the amount of qualitative confirmatory evidence we had on the subject from innumerable users, we felt that there might be some hesitation on the part of others in accepting it, and we accordingly decided to make a series of tests which should, if possible, be so conclusive as to admit of no dispute.

We took six irons constituting three pairs, the irons of each pair containing the same silicon (approximately) but having a very different fracture and different strength, as shown by test bars cast from the furnace. The silicon of the three pairs was about 1.90, 1.00, and 0.70 per cent. (See Table I., p. 11, for complete analysis.) We remelted these in twin crucibles, as will be described later, and cast test bars from the remelts.

In addition to the silicon we determined the graphitic and combined as well as the total carbon in each iron, both before and after remelting. We also made photomicrographs of the original pig and

of a test bar from the remelt, both etched and unetched, for each of the six irons. We have arranged these in groups of eight, each representing one of the pairs. These show at the left the photomicrographs of the original iron; at the right, those of the remelts. Above in each case are the good irons, below are the poor ones. Underneath the photographs are given the silicon, and the breaking strength of the 1.25-in. bars. All of the specimens were taken from corresponding places in the pig or test bar, and are fairly representative of the structure as a whole.

We believe that these data in this form will carry conviction to the minds of even the most unwilling, and that no one will ever be able, in the face of this evidence, to contend successfully that there is not some quality in iron which persists on remelting and is independent of its analysis for ordinary elements.

In order to show quantitatively the relation between strength, combined carbon, and graphite, we made combined carbon determinations, by difference in all cases, on the 1-in. bars, but the greater chilling of 1-in. bars in the Medium No. 8 iron threw the combined carbon far beyond the eutectoid ratio, and we did not think this constituted a fair comparison. We therefore ran the combined carbon in all the 2-in. bars, taking the sample from the exact center of the broken face of the 2-in. bar, so as to make the results as nearly comparable as possible in each case. These results are shown in Table I.

In pair 1, silicon 1.90 per cent., the combined carbon in the strong iron was 0.65 per cent., and in the weak iron 0.78 per cent. The graphite in the strong iron was 3.40 per cent., in the weak iron 3.30 per cent.

In pair 2, 1.00 per cent. silicon, the strong bar contained 0.96 per cent. combined carbon, the weak iron 1.13 per cent. The graphite was exactly the same in both, 3.00 per cent.

In pair 3, 0.70 per cent. silicon, the combined carbon in the strong iron was 1.20 per cent., in the weak iron 1.29 per cent. The graphite in the strong iron was 2.90 per cent., that in the weak iron 3.20 per cent.

In every one of these cases it will be seen that if we take account only of the quantity of combined carbon as increasing the strength of the matrix and that of graphite as reducing the same, we shall get results exactly opposite to the actual ones, except as regards the graphite in pair 3, and even here the difference in favor of the strong iron is slight. It may be that the matrix is somewhat stronger in the strong iron, but inspection of the three sets of photographs with an unprejudiced mind will force one to the conclusion that the principal

reason for the difference is the shape and size of the graphite formed in the two cases, and that quantitatively this difference is ample to account for the difference in strength.

It seemed inconceivable that a quality which would survive remelting and superheating to a point well above the fusion point, as in foundry practice, should be a purely physical quality. In other words, if one iron were better than another because cast at a lower temperature, for instance, and for no other reason (both being identical in analysis); when both were remelted to the same temperature and recast under the same conditions, it is incredible that they would not lose the difference in quality due to this difference in original casting temperature. As the difference in quality evidently did persist in spite of remelting, it seemed to me necessary to believe that the difference was a chemical one.

THE EXPLANATION TO BE SOUGHT IN THE COMMON GASEOUS ELEMENTS

As a consequence of this conclusion and of the establishment to our satisfaction of the second fact above mentioned, that the less common elements were not responsible for these differences in quality in general (though undoubtedly they exert marked influence in special cases), it seemed inevitable that some of the common elements, not ordinarily determined, must be accountable for these variations in quality. Of these, the most universally present in the blast furnace, oxygen, nitrogen, and hydrogen, are the most common and seemed a likely field for investigation.

In regard to hydrogen, it was a very simple matter to test for its presence in the form of water vapor in the current of oxygen passing through the combustion furnace in carbon determinations, and accordingly precautions were taken to see if any water vapor could be detected in the oxygen current, but with an absolutely negative result. This, of course, was not surprising in view of the small quantity of hydrogen in the hearth of the furnace compared with the quantity of nitrogen and oxygen present, and in view of the results of recent investigations along this line. All of the latter prove that while hydrogen is absorbed by iron with avidity at low temperatures, it is all driven off on raising the temperature to a point much below that of the blast furnace.

There remained, therefore, as likely fields of investigation, oxygen and nitrogen.

Oxygen in Coke Irons

Some metallurgists have taken the view that it was impossible for oxygen to exist in the presence of so highly carbonized a product as cast iron, and at so high a temperature as that of the blast furnace, but about 10 years ago I had made certain observations which seemed to me to indicate strongly the presence of oxygen in cast iron, and I did all that I could to get the matter investigated then by those competent to do the work. I wrote to a number of distinguished chemists and metallurgists, told them what I had observed, and begged them to take the subject up and follow it to a conclusion, I not being a chemist myself and having no chemist in my employ at that time capable of working the matter out. Some of those to whom I wrote were politely indifferent and others mildly interested, but too busy on other things to concern themselves with such an investigation.

The facts observed at that time have a sufficient bearing on the present matter to justify their presentation here.

The furnaces of the Longdale Iron Co., in whose employ I was at that time, ran continuously for many years on basic iron, with an absolutely constant ore mixture and with a blast temperature which was, to all intents and purposes, unvarying from one year's end to another, 850° F. Careful and long continued observation of the appearance of the iron, and particularly of the small sample chill pig made at each cast, in conjunction with the analysis, taken with the working of the furnace itself and the character of the running iron, brought out clearly certain conditions which prevail to a certain extent at all plants, but not so conspicuously at those with less constant conditions.

Marked differences in the fracture of the iron for a given analysis were observable according to whether the iron was "wild" on irregular furnace conditions, or whether the operation was normal and the iron "quiet."

On white irons, in good normal working condition of the furnace, the fracture of the chill pig was practically square, with clearly marked acicular crystals running perpendicularly from the chilled surfaces of the pig, even from the top in some cases, and clearly showing lines running from the center to the corners, these lines being where the sets of crystals from adjacent sides met.

On a "wild" iron of similar analysis the fracture was smooth, but conchoidal rather than square, with a complete absence of crystals radiating from the sides of the pig, and, of course, a corresponding absence of the interference lines of these adjacent sets of crystals running to the corners.

Irons with higher silicon when made on a smoothly running furnace had a comparatively slight chill. Such as there was showed strongly marked acicular crystals similar to those in the white iron, the grain quite open and the color light. When made on a wild-working furnace, iron with approximately the same silicon had greater chill with absence of crystals, while the gray portion was exceedingly fine grained, and dark, almost purplish in color, so as to give it a velvety appearance.

In coke practice a wild-working furnace is almost always associated with higher sulphurs, and the irons last described, both white and gray, came to be cordially detested as showing, even in advance of analysis, high sulphur.

It is a matter of much interest to observe that the white irons showed in an increasing degree, as they became wilder, cleavage surfaces which were discolored with the blue, red, and purple "oxide colors." This was commonly attributed to oxidation by the absorption of air into cooling cracks in the pig, but I have seen many cases when these surfaces could only be broken apart by the most tremendous sledging, and this never seemed to me to correspond with the idea of a crack of sufficient width to permit the ingress of air.

These "wild" irons, particularly the harder ones, as they cooled, threw off a scale of considerable thickness, continuous at first and detaching itself from the surface of the pig in slabs frequently as large as one's hand. Thinking that this scale might be an indication of something, I had it analyzed for sulphur, with the surprising result of finding only about one-third as much sulphur in the scale as was in the iron.

After the chemist who made this analysis had left, I was discussing this remarkable result with his successor, who had been the assistant at that time. He told me that the analysis had been made by the evolution method, and that if the sulphur were in the oxidized condition it would not be given off by this method, causing a low result, and that it would be necessary to use the gravimetric or fusion method to obtain correct results in this case.

On the first subsequent occurrence of this scale I accordingly had an analysis made by the latter method, with the result of finding, instead of one-third as much sulphur as in the pig, about three times as much.

About this time Prof. E. D. Campbell, of Ann Arbor, published a paper describing the remarkable ability of the oxysulphides of iron and nickel to penetrate the solid walls of iron tubes. It then seemed

possible that this scale might be an oxysulphide, which exercised this peculiar penetrating power to make its escape through the crystals of the solidifying pig, and gathered on its surface.

If this were true, then the "wild" irons which showed this scale should contain some of their sulphur in the oxidized condition, and the results obtained by the ordinary volumetric analysis for sulphur would show a lower result in such irons than the gravimetric, whereas, in the irons on a normal working furnace (in the absence of titanium) a small and constant difference is found. Accordingly, it seemed that the difference between the volumetric and the gravimetric sulphur should increase from normal iron to "wild" iron.

Quite a number of comparative analyses were made to determine whether this were actually true, and the results confirmed this theory to a remarkable degree. Of something like 12 irons picked to show either a high or a low difference between volumetric and gravimetric sulphur, according to the way the furnace was working, about 10 showed the expected result. No record, unfortunately, has been preserved of this work, but I remember that in one case the gravimetric sulphur was 50 per cent. higher than the volumetric, the latter being 0.034 and the former 0.051 per cent., this being on a particularly "wild" iron.

Oxygen in Charcoal Irons

When I first began making charcoal iron, the founder told me of "special cylinder" iron, which he described as "an iron with a No. 2 analysis and a No. 3 fracture, made when the furnace was coming up out of a scrape." I asked to be shown a specimen of this iron, and being struck by its absolute similarity of appearance to the "wild" gray iron made on a coke furnace under similar conditions, I was at once convinced that it contained oxygen and that the notion of its superiority to ordinary iron was an erroneous one; and I condemned it without qualification.

I was strongly of the opinion then that the more easily reducible the ore the better would be the iron, because the more thoroughly deoxidized it would be. This was very strongly the opinion of William Wilkins, General Superintendent, and he accordingly bought some Mesabi ore of first-class physical structure, containing about 7 per cent. of combined water; in other words, a fine limonite; and we made a test with this ore, substituting it for our regular Gogebic hematite, a little at a time.

We had by that time instituted the making of test bars from every cast, and could observe directly the variations in the strength pro-

duced by different conditions. We found that the strength of the iron fell steadily as the percentage of Mesabi increased, so that it dropped from 2,800 or 2,900 lb. on a 1.25-in. test bar to about 2,400 lb. when we had on from 75 to 80 per cent. of the fine limonite. We then took off the Mesabi, got the furnace back on to an all soft-hematite burden and repeated the experiment, with absolutely identical results.

About that time my attention was called by another furnace-man to coke irons made on an all-limonite burden, which were of beautiful analysis, soft, open grained, and exceedingly weak. It then occurred to me that we had disliked the "wild" coke irons because they were generally associated with high sulphur, without regard to their physical characteristics, and, on thinking it over, I realized that they were not infrequently exceedingly strong, tough irons; and finally it seemed to me likely that by reversing my former opinion absolutely we might perhaps get a theory which would conform more closely to the facts, and that it might be the presence of a certain amount of oxygen (in what form I do not pretend to say) that produced certain characteristics as to fineness of grain, chilling qualities, strength, and toughness, which are so much desired. It is now more than two years ago that I began to work on this hypothesis with all the means at my command.

I have previously mentioned a product virtually unknown at coke furnaces, which we call spongy No. 6. This is an iron made on an exceedingly cold furnace, perfectly white, and filled with a mass of blow-holes so great as to occupy up to a half or even more of the volume of the metal. The walls of these blow-holes are as white as silver. The cause evidently is the descent into the hearth of a mass of incompletely reduced iron, which, mixing with the liquid iron already present, sets up an action almost like that in an open-hearth furnace. The silicon is removed down to the barest trace, 0.03 per cent. or so, and the carbon is then attacked and oxidized from the normal 3.50 to 4.00 per cent. down nearly to 3.00 per cent. in some cases. The iron, being very cold and low in carbon, is naturally very pasty and chills without giving a chance for the escape of the CO formed by the oxidation of the carbon.

It was evident that this iron must contain a great quantity of oxygen, and that if this were really the cause of strength and the other desired qualities in iron it could be secured by making a mixture of this spongy No. 6 and a normal iron. Such a mixture was accordingly melted in the crucible, and test bars made therefrom showed results as strong or stronger than the best iron ever made

from the furnace; 1.25-in. round bars on 12-in. centers breaking up nearly to 5,000 lb. as against an average of about 3,000 lb. for normal irons.

ATTEMPTS TO PRODUCE SPECIAL IRON AT WILL

It then seemed that we had only to introduce oxygen into the hearth of the furnace to make an iron as good as the best. The easiest way to do this seemed to be to cause irregular working of the furnace and this we proceeded to try out by purposely distorting the filling for several hours. We undoubtedly upset the regular running of the furnace, but the iron was no better, probably somewhat worse than before. We then put a medicine valve on the bustle pipe, filled it with mill scale and blew it into the hearth just before cast time, with little or no result, and such as there was, a detriment to the quality. This was repeated several times.

We then began ladle experiments, heating iron ore and other kinds of oxides in the bottom of a ladle before cast time and running iron in on them at cast, stirring up the mixture and pouring test bars and sample pigs. By this means we did close up the grain of the iron and induced a paper chill (that is, a line of white no thicker than a piece of paper around the edge of the pig), which was not present in the regular cast, but when it came to improvement in strength and toughness there was little or none to be observed.

During the early part of this investigation descriptions of the Ledebur apparatus for the determination of oxygen in iron and steel as modified by the chemists of the American Rolling Mill Co. were published, and we bought a set of this apparatus and began direct determination of oxygen. This determination in the presence of 3 or 4 per cent. of carbon is a very different matter from its determination in steel, and it took some time to learn all the precautions necessary to secure low blanks and concordant results.

This end, however, was attained in time. We first made a determination of oxygen in some of the spongy No. 6 and found it to contain as high as 0.13 per cent. We then took cold-blast irons and special cylinder irons and found these to range as high as 0.07 per cent. We then took normal charcoal irons and found them to contain only about 0.015 per cent.; foundry coke irons and electric-furnace irons contained none at all. We were unable to secure samples of "wild" coke basic iron such as described above, but I have no doubt that analysis would show the presence of oxygen in this.

METHOD OF MAKING REMELTS

As many of the data in this article are derived from tests of remelts, it seems desirable to state that all the remelts mentioned or tabulated in this paper are made in a "coke hole," approximately elliptical in shape so as to take two crucibles at once, and provided with two tuyeres at opposite ends of its long diameter, so that both its crucibles would be subjected to the same intensity of combustion, etc. In all cases where directly comparative results of a given treatment have been sought iron from the same cast has been used in each crucible, melted at the same time, and the two poured within a few minutes of each other; one with, the other without the desired treatment. We have endeavored to get two 2-in. square bars, two 1-in. square bars, and two 1.25-in. round bars, all cast on end, from every such heat, but not having a skilled molder on this rather difficult work, we have not always succeeded in getting a complete set of perfect bars. There is also, of course, a variation to be expected in these bars on account of the nature of the material and on account of their being industrial rather than laboratory or refined tests.

RESULTS OF REMELTS

We repeated many times the experiment of remelting normal or even very poor ("spotted") irons, with spongy No. 6, and with the same result in every instance, an improvement in the strength up to 50 per cent or more.

We give in Table I. a summary of the results on the three pairs of remelts mentioned earlier, which shows their chemical composition and also the strength of the original iron and of the remelts.

It will be seen that in every case those irons which were strong as they came from the furnace retained their superiority after remelting. It will also be seen that the good iron was in each case much higher in oxygen than the corresponding poor iron. To summarize, therefore, we consider that we have proved the following facts:

1. Strong, tough irons of high chilling qualities contain oxygen in appreciable quantities. Weaker irons of similar analysis contain less or no oxygen.
2. Poor and normal irons may be improved beyond recognition by introducing oxygen into them.

EXPERIMENTS ON DEOXIDATION

As an additional proof that the actual cause of the increased strength of the strong irons was oxygen, we thought it would be well to try

TABLE I.

Original Iron. Cast No.	Kind.	Remelt No.	Breaking Strength.		T. C.	G. C.	G. C.	Si.	Mang.	Phos.	Sul.	N.	O.	Micro-graph. No.	Fracture.
			1.25-in. Rod. Bar.	2-in. Square. Bar.											
A	Soft 1	.....	3,000 3,350	.....	4.00	3.22	0.78	1.90	0.62	0.139	0.017	0.006	0.027	1 & 2	Close grain for grade.
A	Soft 1	R. 291	3,150 3,200	16,000 16,900	4.05 4.05	3.40 3.05	0.65 1.00	Sample taken Sample taken		from 2 in. bar from 1 in. bar				5 & 6	
B	Spl. 1	.....	2,500 2,900	.....	4.09	3.43	0.66	1.88	0.70	0.112	0.020	0.0030	0.009	3 & 4	Very open, low chill.
B	Spl. 1	R. 292	2,600 2,700	13,000 13,900	4.08 4.03	3.30 3.29	0.78 0.79	Sample taken Sample taken		from 2 in. bar from 1 in. bar				7 & 8	
C	High 2	.....	3,400 3,500	.....	4.00	3.05	0.95	1.00	0.46	.....	.....	.....	0.038	9 & 10	Close grain, $\frac{1}{4}$ -in. chill.
C	High 2	R. 297	3,800 3,700	16,000 16,000	3.95 3.95	3.00 2.96	0.96 1.00	Sample taken Sample taken		from 2 in. bar from 1 in. bar				13 & 14	
D	High 2	.....	2,400 2,900	.....	4.05	3.15	0.90	1.00	0.50	.....	.....	.....	0.009	11 & 12	Open grain, no chill.
D	High 2	R. 298	3,000 2,800	14,900 12,000	4.13 4.13	3.00 3.16	1.13 0.97	Sample taken Sample taken		from 2 in. bar from 1 in. bar				15 & 16	
E	Med. 3	.....	3,500 4,200	.....	4.10	3.50	0.60	0.70	0.60	0.128	0.035	.....	0.065	17 & 18	Very close grain, 0.25-in. chill.
E	Med. 3	R. 301	4,150	19,300 20,900	4.10	2.90	1.20	Sample taken		from 2 in. bar				21 & 22	
F	Med. 3	.....	2,500	.....	4.49	3.60	0.89	0.72	0.59	0.108	0.024	.....	0.009	19 & 20	Open grain, $\frac{1}{4}$ -in. chill.
F	Med. 3	R. 302	2,750	10,900 12,900	4.49	3.20	1.39	Sample taken		from 2 in. bar				23 & 24	

the effect of deoxidizing some of these strong irons with recognized agents used for that purpose. We accordingly made various remelts of strong irons which we deoxidized in the crucible immediately before pouring with aluminum in several cases and with titanium in one or two. The results are shown in Table II. The results of the first trials are given by Nos. R 278, R 303, R 279, and R 304. They did not seem to us as conclusive as they should be and we came to the conclusion that the aluminum in particular, on account of its being so much lighter than the iron and in the form of fine shot, could not be properly mixed with the contents of the ladle to secure the desired result. We therefore made two additional remelts, R 305 and R 306, in which we used a piece of scrap aluminum, weighing about 1 oz., for each crucible holding 50 lb. of iron. This scrap aluminum was securely fastened to the end of a slender iron rod. It was thrust down to the bottom of the molten iron in the crucible and stirred around until all the aluminum was gone. The results in this case were decidedly more conclusive, as will be seen by the last two comparative lines in the table, but even in this case the iron was not as weak as normal irons. We therefore determined the oxygen in the test bars and found it to be 0.018 per cent. in R 305, and 0.021 per cent. in R 306, thus showing that in spite of this drastic treatment the oxygen was not completely removed and accounting for the comparatively high strength of the iron even after the deoxidizing treatment.

The results with titanium are confirmatory of the results with the aluminum. The strong irons deoxidized with about 1 oz. of 10 per cent. ferro-titanium per 50-lb. crucible were greatly weakened.

We believe that these results may be taken as a final and conclusive proof that oxygen in some form not known or understood by us is accountable for the abnormal strength of irons whose analysis as regards other elements is normal.

THE CONDITION AND DETAILED EFFECTS OF OXYGEN

As to the condition in which this oxygen exists, we know nothing. We have been unable to detect it with the microscope, and we can only assume that it is some oxide of very much lower degree than any with which we are familiar.

Its effects seem to be two-fold:

1. It makes the iron very much more sensitive to chilling influences. One of these good irons if cooled normally will be only slightly harder than a normal iron, and on account of its fine, close grain will machine beautifully, but if the surface be chilled even slightly it begins to whiten up, and with a chill of any strength

TABLE II.

[illegible]

will be solid white at the edge, where a normal iron of the same silicon would show little chill, or none at all.

2. The other principal effect is shown by the photographs, Figs. 1 to 24, and consists in the extremely fine subdivision of the graphite in the strong irons, contrasting conspicuously with the large, coarse aggregates of graphite in the weak irons. Comparing these photographs of strong irons with those of malleable iron cast white and graphitized by annealing, one is struck with the resemblance, and it is easy to suppose that the effect of oxygen is to raise the solidifying point of the iron relative to the temperature of evolution of the graphite so that the latter, instead of being free in the liquid mass to assume as bulky a form as it chooses, can only form against great pressure and must therefore form in the most compact particles possible, which, in turn cannot coalesce into larger masses because of the resistance of the surrounding medium. These are purely scientific points outside the field of a commercial investigation, and beyond our power to investigate.

A further condition which exists in these high-oxygen irons is that the tendency to form plates of eutectic and to form a spot in the center of the pig is entirely suppressed, no matter what the silicon of the iron may be, even with quite high carbons. We believe this to be a direct effect of the presence of oxygen, but as the total carbons are generally lower in the strong iron than they are in the weak ones, and as the tendency to form eutectic has been previously shown to depend on high carbon, we cannot absolutely prove whether its absence is the effect of the high oxygen content or of the low carbon content. Some of the strong irons, however, as will be seen from Table I., are quite high in total carbon; in fact, are as high as some irons in which distinct cleavage and corresponding weakness have been observed, so we feel practically certain that this highly beneficial suppression of eutectic formation is a third valuable consequence of high oxygen content.

The unvarying association of high cleavage due to eutectic formation with low chilling power in weak irons, and of high chilling power with a suppression of eutectic formation in strong irons, leads one to wonder if there is not some connection between these phenomena; whether, in fact, the eutectic may not be unstable and tend to break down into ferrite and graphite with consequent absence of chill, whereas, the austenitic formation previously shown to be characteristic of good irons may tend to establish a stable equilibrium in the pearlite conditions with consequent higher combined carbon.

These are merely suggestions for scientific metallurgists to consider, and discard or accept at their pleasure.

COMPARISON OF HIGH OXYGEN CAST IRON AND MALLEABLE CAST IRON

Returning for a moment to the resemblance of these high oxygen irons to malleable, it may well be that this resemblance is more than accidental. The best malleable iron is made in the air furnace rather than in the cupola, and in the air furnace the conditions are entirely oxidizing, while in the cupola they are very largely reducing. A bath of white iron low in silicon at a low temperature in the oxidizing atmosphere of an air furnace might easily be capable of absorbing a certain amount of oxygen, which would tend to give a good strong white iron casting before malleablizing.

It is a matter of common knowledge that good charcoal iron makes a far better raw material for the production of malleable castings than coke iron. On the other hand, there has been much trouble in the malleable industry from attempts to use spotted charcoal irons. (See discussion by Bradley Stoughton of my paper, *The Effect of High Carbon on Charcoal Iron*.) These are irons which I shall presently show are made under conditions tending not only to super-carburization but to thorough deoxidation, which, in fact, analysis proves to take place.

Considering all these circumstances, it seems at least possible that good malleable castings are most easily made from high-oxygen charcoal irons, because the oxygen has the tendency to throw the carbon into the combined condition, and, therefore, give the necessary chill to iron high enough in silica to be "live," at the same time throwing any graphite which may form in the original casting into the nodular form, the same as that into which it is forced by annealing.

The use of the air furnace does not completely replace the best grades of charcoal iron because its conditions are less favorable to the absorption of a large quantity of oxygen than the conditions in the hearth of a relatively cold blast furnace, which receives a certain amount of incompletely reduced iron sponge in the virtual absence of silicon, whose presence would prevent its absorption by the bath.

REASON FOR LOW OXYGEN CONTENT ORDINARILY

It seems desirable here to point out why it is virtually impossible to get much oxygen into an iron except when the furnace has been in a "mess," and to point out the relation between this fact and the commercial absence of irons of similarly high quality from coke furnaces under the same conditions.

¹ *Trans.*, xliv, 354 (1912).

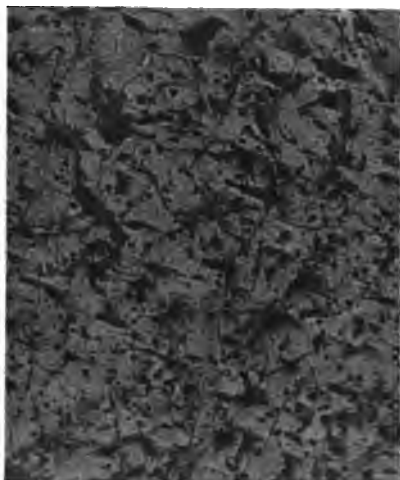


FIG. 1.—UNETCHED.



FIG. 2.—ETCHED.

Magnified 100 diameters.

GOOD IRON. Silicon, 1.90; Oxygen, 0.27 per cent.

Breaking strength, 1.25-in. bar, 3,000 lb., 3,350 lb.



FIG. 3.—UNETCHED.



FIG. 4.—ETCHED.

Magnified 100 diameters.

POOR IRON. Silicon, 1.88; Oxygen, 0.009 per cent.

Breaking strength, 1.25-in. bar, 2,500 lb., 2,900 lb.



FIG. 5.—UNETCHED.



FIG. 6.—ETCHED.

Magnified 100 diameters.

REMELT. Silicon, 1.90 per cent.

Breaking strength, 1.25-in. bar, 3,150 lb., 3,200 lb.



FIG. 7.—UNETCHED.



FIG. 8.—ETCHED.

Magnified 100 diameters.

REMELT. Silicon, 1.88 per cent.

Breaking strength, 1.25-in. bar, 2,600 lb., 2,700 lb.

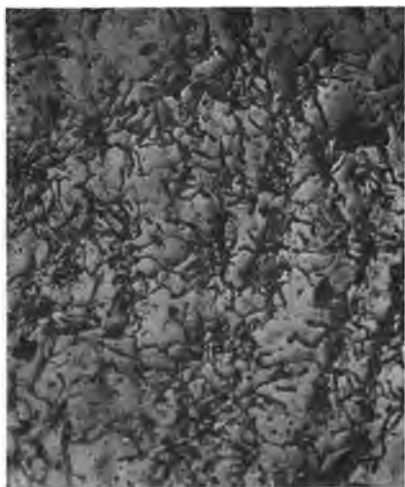


FIG. 9.—UNETCHED.



FIG. 10.—ETCHED.

Magnified 100 diameters.

GOOD IRON. Silicon, 1.05; Oxygen, 0.038 per cent.

Breaking strength, 1.25-in. bar, 3,400 lb., 3,100 lb.



FIG. 11.—UNETCHED.



FIG. 12.—ETCHED.

Magnified 100 diameters.

POOR IRON. Silicon, 1.00; Oxygen, 0.009 per cent.

Breaking strength, 1.25-in. bar, 2,400 lb., 2,900 lb.



FIG. 21.—UNETCHED.



FIG. 22.—ETCHED.

Magnified 100 diameters.

REMELT. Silicon, 0.70 per cent.

Breaking strength, 1.25-in. bar, 4,150 lb.



FIG. 23.—UNETCHED.



FIG. 24.—ETCHED.

Magnified 100 diameters.

REMELT. Silicon, 0.72 per cent.

Breaking strength, 1.25-in. bar, 2,750 lb.



FIG. 25.—ELECTRIC FURNACE PIG IRON.
Magnified 100 diameters.



FIG. 26.—ELECTRIC FURNACE PIG IRON.
Magnified 100 diameters.

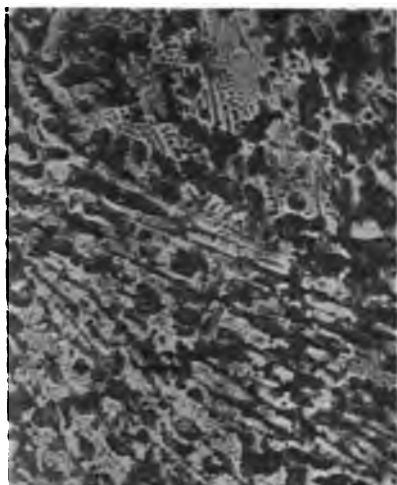


FIG. 27.—CHROME, 4 PER CENT.
Iron used as base was extra good special cylinder. Compare this with Fig. 14.



FIG. 28.—CHROMIFEROUS FIG.
Note resemblance to spotted weak iron in Fig. 27.

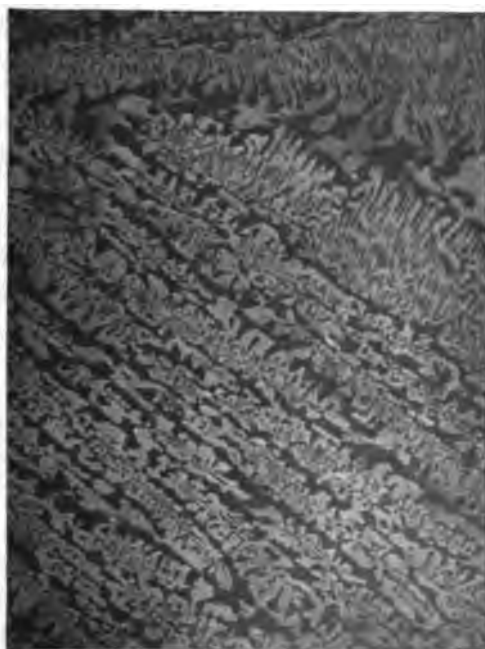


FIG. 29.—TYPICAL SPOTTED IRON.
POOR IRON (Spotted). Etched. Magnified 100 diameters.

The increase in the affinity of carbon for oxygen is well known to be extremely rapid with increase in temperature. The affinity of silicon for oxygen and the ease with which silicon may be oxidized by oxides of iron is similarly well known. When, therefore, we attempted to introduce oxygen into the iron by disturbing the regularity of the working of the furnace or by blowing in oxide at the tuyeres, we did introduce iron oxide into the bath; but, in the presence of an ample supply of heat and incandescent carbon, this oxide was instantly attacked by either the silicon or the carbon and reduced to metallic iron, which passed into the bath without effect. The same thing happened when we introduced heated iron oxide into a ladle full of iron. The oxide attacked the silicon in the bath and was reduced to metallic iron, with the oxidation of silicon to silica. Probably also carbon may have been attacked to some extent, but no oxygen ever became united with the iron of the bath because of the superior affinity which silicon and carbon have for it at these temperatures.

It is, however, a well-known fact that once iron has taken up oxygen it is exceedingly difficult to remove it even with powerful deoxidizing agents. The steel makers, I believe, now recognize that they get occasional casts of iron of faultless analysis from which good steel cannot be made in the Bessemer or open-hearth furnace, no matter how much deoxidizer may be used, but these irons may be completely deoxidized and made into first-class steel in the electric furnace on account of its power to maintain a reducing atmosphere and an exceedingly high temperature for an indefinite period.

CONDITIONS FOR HIGH OXYGEN CONTENT

It seems, therefore, that when the temperature of the hearth of the furnace has become lowered by the descent into it of a mass of relatively cold and imperfectly reduced material, this low temperature and the practically complete absence of silicon permit a certain amount of oxidized material to be dissolved in the bath in spite of the presence of more than 3 per cent. of carbon. It would seem as though this material were an imperfectly reduced iron sponge, which, either from a deficiency of heat or a deficiency of carbon in the hearth, had never given up its last traces of oxygen, but passed into the bath in this condition. This material, having once become incorporated with the iron, is not deoxidized by any ordinary subsequent reaction.

If, now, the furnace be cast while this condition prevails we shall get spongy No. 6, but if the iron be held in the hearth until additional fuel comes down and restores the regular operation of the

furnace, the normal iron so made will descend into the bath of spongy No. 6, will liven it up and impart silicon to it, and will, perhaps, reduce, but will not completely eliminate, the oxygen it contains. If the furnace be cast after these conditions have prevailed for a sufficient period, we shall get a cast of special cylinder iron.

When we remelt a normal iron with the spongy No. 6 in a crucible, we do no more than repeat on a small scale what the furnace does on a large scale when the conditions are right.

COKE-FURNACE CONDITIONS AS REGARDS OXYGEN

In a coke furnace the conditions are entirely altered, because, as is universally understood, such a reduction in temperature with that fuel is almost inevitably accompanied by a rapid increase in the absorption of sulphur by the iron, and this element seems to introduce a totally different set of conditions.

This is probably the result of two facts:

1. That the hearth temperatures in coke furnaces are necessarily much higher than those in charcoal furnaces on account of the greater infusibility of their slags, and even after such reductions are far above that at which spongy No. 6 is found in charcoal furnaces.

2. Because it seems probable that the sulphur combines with the oxygen and that the oxysulphide has a vastly different effect on the quality of the product from that of oxygen in the absence of sulphur.

I do not wish to be understood as claiming that we have proved that oxygen will unite with sulphur when the latter is present to any considerable extent, and so form an oxysulphide; for I have no direct proof to offer that this takes place. At the same time, the marked difference between the sulphur by the evolution method and that by the gravimetric method in "wild" coke irons, above described, seems to me a strong indication in that direction. Moreover, the wild coke irons seem to follow a different line of development from the wild charcoal irons; for instance, spongy No. 6, which is not infrequently made at charcoal furnaces, is almost unknown at coke furnaces. Those who have made medium sulphur white irons in a coke furnace ("basic") know that this iron when broken shows oxide colors on all the cleavage faces. These are so pronounced and brilliant (ranging from red to purple) as to eliminate the white appearance of such iron completely in some cases, and a very wild coke iron cast into a chill sample pig and cooled off quickly with water will break up into little cubes like dice, of which the faces are every color from purple to black, but practically never white.

These phenomena are practically never absent in charcoal irons. The temper colors are rarely seen. The wildest of all the iron made, spongy No. 6, shows little or no tendency to break up into cubes, and in general there is but little resemblance between the two varieties of wild iron, whose only important difference, so far as known to me, is the considerable quantity of sulphur in the one and the small quantity in the other.

In the course of close observation of coke iron extending over a number of years, I came to the conclusion that the effect of oxygen was to augment the effects of sulphur so that a wild iron with high sulphur was more objectionable; that is, weaker and more prone to break into small pieces by contraction cracks when hard, than an iron with the same sulphur but not made on a wild-working furnace. This view is not capable of proof by absolute evidence, for unfortunately I cannot offer any such as that with which I have aimed to support my more positive conclusions. At the same time, a conclusion of this kind based on years of careful observation has to my mind a certain value, and I am submitting it here for what it may be worth.

THE HEAT BALANCES OF DIFFERENT KINDS OF FURNACES

It seems desirable to point out here certain factors concerning the heat balance of the blast furnace with different fuels and different slags, as well as different blast temperatures, because they affect this problem vitally.

By the heat balance I do not mean merely a statement of the total number of thermal units developed and introduced by the blast minus those carried out by the top gases, but a balance taking account of the quantities both of high-temperature and of low-temperature heat developed in any furnace under given conditions.

The theory that the blast furnace has a critical temperature, which is in effect the free-running temperature of the slag, and that the heat necessary for the hearth reactions can only be that available in cooling the gases formed at the tuyeres from their theoretical combustion temperature down to this critical temperature, seems to have been accepted widely enough to justify its use for making a more instructive heat balance.

We have been able, ever since Bell's researches, or before, to calculate the total heat imparted to the furnace. By the use of this critical temperature theory we are able to figure the amount available for the hearth under any given conditions when the free-running temperature of the slag is known. It is obvious that there must be some more or less distinct relationship between these two

quantities of heat. A certain amount is necessary for the reduction of the ore and for bringing the iron and slag-forming materials up to the critical temperature. A certain further amount is necessary for actually melting them and for the completion of the reduction process in the broadest sense.

It is obvious that the ratio which these two quantities must bear to one another can only vary to a considerable extent through a great variation in the character or quantity of the slag, the nature of the ore, or some other fundamental variation of furnace conditions.

I formerly called the high-temperature heat utilized in the hearth and bosh the "available" heat, but for the purposes of this discussion I now propose to substitute for this the term "hearth" heat, because I shall show that some of this available heat passes up out of the hearth and so becomes "available" in the shaft of the furnace, thus leading to confusion. The heat applied for purposes of reduction and preparation in the shaft of the furnace I have called "shaft" heat. I recognize the clumsiness of these terms and will accept with gratitude any better ones which may be offered.

The hearth heat is found by adding to the heat of combustion of the fuel burned in the hearth that brought in by the blast, and deducting that required for the dissociation of the moisture in the blast and for raising the temperature of all the gases of combustion to the critical temperature.

The shaft heat is the last-mentioned sensible heat in the gases of combustion, plus the heat developed in the shaft by the further oxidation of the gases from the fuel by oxygen from the ore, less the sensible heat carried out by the top gases.

Pyrometric observations carried on for most of the past three years have indicated the free-running temperature of charcoal slag to be about $2,300^{\circ}$ F., as against about $2,700^{\circ}$ F. for coke slags in ordinary practice.

Comparing the results of the dry-blast coke run, published in James Gayley's paper on that subject some years ago, with our own practice, I found that the coke furnace at Isabella was developing about 1,000 thermal units of hearth heat per pound of iron, while in our practice at that time we were developing between 1,100 and 1,200, although our slag volume was only about one-half of that at Isabella.

This surprising result, after careful consideration, could mean only one thing, that we were developing in the hearth more heat than was required for the operations of the hearth; that part of the excess was expended in superheating the iron and slag above the temperature

necessary, the balance passing up into the shaft of the furnace and being utilized there, although at a lower temperature.

An exhaustive calculation of heat balances in coke and charcoal furnaces in the sense above described, indicated very clearly that the limiting quantity of heat in the Lake Superior charcoal furnace was not in the hearth, as in coke furnaces, but in the shaft. This is borne out by the fact that a change in blast temperature of 800° or 400° on such a charcoal furnace will only change the iron a couple of grades, whereas, in coke practice it would mean almost the difference between regular operation and "chilling." This is obviously for the reason that only a certain definite supply of hearth heat is necessary and after the heat of the blast has completed this supply any additional heat in the blast serves only as additional shaft heat and the saving can only be reckoned in percentage of the total shaft heat. The saving is therefore only about one-fourth as great as that made by an equal quantity utilized as hearth heat.

In the case of the hot-blast charcoal furnace above described, the heat developed in the hearth is actually capable of taking care of much more ore, but the gases in the shaft are not able to reduce any more because they are cooled far below the temperature of possible reaction when they leave the top of the furnace, not infrequently to 200° F. or below. For convenient reference let us call this Case I.

The consequences of this condition are far-reaching and are difficult to realize by those accustomed only to coke practice on lean or refractory ores, where every increase in the hearth heat corresponds to an exactly proportionate reduction in fuel consumption. In those furnaces there is always a great excess, either actual or potential, of shaft heat; that is to say, if the top gases are not themselves so hot as to be capable of much further action on the ore, they are so rich in carbon that they could be oxidized to a far greater extent with the oxygen from additional ore, if only the heat developed in the hearth were able to take care of the ore so reduced. (Case II.)

These two types of furnaces, hot-blast charcoal, and coke with lean or refractory ores, represent two opposite types as far as their heat balances are concerned. The former has a relative deficiency of heat in the shaft, the latter in the hearth.

There are two other groups of furnaces, the first of which belongs to one of these types, the second to the other. These are the coke furnace using rich and easily reducible ores, and the cold-blast charcoal furnace.

In the latter the hearth heat developed per pound of fuel is only

about four-tenths of that developed in the hot-blast charcoal furnace, so that while the amount of fuel used in these furnaces is much larger than that used in the hot-blast furnaces, the hearth heat developed per pound of iron is so much less than in that case as to make the heat balance like that of the coke furnace on lean ores; that is, to make a marked deficiency in the hearth as compared with that developed in the shaft. (Case III.)

The first group above mentioned, coke furnaces on rich and reducible ores, embraces those furnaces making the greater portion of the pig iron output of the country. They are in general well equipped with stoves and it is notorious that it is often impossible for them to use all the heat that they can get, because the operation of the furnace is deranged by anything more than very moderate blast temperatures. These furnaces, on the other hand, work with very cold tops, the gases commonly passing off at a temperature well below that at which any reaction on the ore can occur, no matter how rich the gas. (Case IV.)

These two facts may be taken as a proof, in a practical way, of the correctness of the results of an accurate calculation of the heat balance, which shows that in these furnaces there is generally an excess of heat in the hearth.

THE EFFECT OF DIFFERENT TYPES OF HEAT BALANCE ON QUALITY OF IRON

Since the quantities of carbon and of oxygen present exercise so large an influence on the quality of the iron, it is worth while to examine the conditions in these four cases with a view to their effect on these two elements.

We know but little about the laws which control the absorption of carbon by the iron, but two facts are established:

1. The greater the quantity of carbon the greater the opportunity for saturation at the given temperature and the more rapidly saturation will occur.

2. The higher the temperature the greater the degree of saturation possible.

We also know, in a general way, some of the laws of deoxidation, of which two may be roughly stated as follows:

1. The greater the exposure to carbon the more complete the deoxidation at a given temperature.

2. The higher the temperature the more complete the deoxidation with a given exposure to carbon.

Case I. A poorly working hot-blast charcoal furnace in which poor distribution, or other irregularity with consequent imperfect reduction, is sought to be overcome by high blast temperatures and high fuel, furnishes the two conditions most favorable for complete deoxidation and high carburization, leading to a hyper-eutectic iron, with its consequent tendency to form eutectic plates and lose its strength thereby. It is under these conditions that we obtain the "spotted" irons of well-deserved bad reputation.

The obvious corollary to this is that when we have a regularly working furnace with a minimum of sudden changes and calls for extra heat to keep it out of trouble, we shall make a better grade of iron. In other words, good furnace work is the first requisite to high quality. In addition to this we can cut down our blast temperature, which, as is well understood, reduces rapidly the hearth heat developed per pound of fuel, until we reach a point where both sides of the thermal equation balance, and at this point we shall have the lowest hearth temperature and the lowest degree of superheating of the iron and cinder, combined with a comparatively small volume of fuel in the hearth.

Further, the inferior quality obtained by our experiments with the easily reducible fine limonite from the Mesabi tends to show that a quantity of hearth heat which may not be too great to give good quality with one kind of ore is excessive for a more reducible variety of ore.

Case II. The coke furnace, on lean or refractory ores, suffers chronically with a deficiency of heat in the hearth. The hearth temperature and that of the iron are closely controlled by the free-running temperature of the slag, and there is little or no superheating.

(Superheating is used in this discussion to mean heating above the free-running temperature of the slag.)

On the other hand, we have a higher temperature and a much greater quantity of fuel in the hearth than in the hot-blast charcoal furnace.

These two factors tending to more perfect deoxidation offset the advantage (from the quality point of view) of having a deficiency of heat in the hearth and these irons are accordingly not so good as charcoal irons; but that they may occasionally contain oxygen is, in my judgment, abundantly indicated by the evidence I have cited, and the fact of their high reputation among coke irons in the foundry trade for the desirable qualities of strength, toughness, and density of grain is too well established to be gainsaid.

This case represents, in a general way, Eastern and Southern coke irons, and the premium which these command in the open market is a sufficient proof of their superiority to the ordinary coke irons made from the Lake Superior ores.

Case III. The cold-blast charcoal furnace uses a considerable quantity of fuel, but so little hearth heat is developed from it that a chronic deficiency exists. For this reason these furnaces run continually on the brink of disaster. Their slag is heated barely to the point where it can be removed from the furnace with the assistance of hooks, hence their hearth temperature is so low that deoxidation, even in the presence of the considerable volume of fuel, cannot be complete, consequently the irons of this variety that we have analyzed always contain considerable percentages of oxygen and are well known to have the highest chilling qualities and strength obtainable with any iron. At the same time, these irons have an ample opportunity for absorbing carbon, and as a matter of fact, those we have analyzed run quite high in that element, frequently around 4.00 per cent. But the detrimental effects of this are eliminated by the presence of oxygen. The latter, as above mentioned, seems to prevent the formation of the eutectic, which causes weakness in high-carbon irons when low in oxygen.

Case IV. Coke furnaces on rich and easily reducible ores have frequently a surplus of hearth heat (as indicated by the inability of the furnace to use a higher blast temperature), a volume of fuel in the hearth not much less than that of the lean-ore coke furnaces, and a degree of superheating of their product which is very striking to the eye of one accustomed only to the corresponding temperatures in Case II.

These are obviously the conditions which lead to the most complete deoxidation and the highest degree of carburization, therefore to poorest quality.

The "rottenness" of castings made from ordinary Bessemer iron in the Lake ore district, especially since the introduction of large percentages of highly reducible Mesabi ore into their mixtures, is accepted as a matter of lamentable but unavoidable fact by those who, like steel-works engineers, have to use such castings exclusively.

Reviewing all four of these cases, we see that they fall naturally into two quite distinct classes:

1. Those furnaces which generate more hearth heat than they can utilize in the hearth and whose controlling limitation to fuel economy is the amount of heat they can develop in the shaft. These conditions

lead to superheating the iron and furnish the best conditions for complete deoxidation and supercarburization. To this class (which we will call for convenience Class I.) belong the hot-blast charcoal furnace and the coke furnace on rich and easily reducible ores.

2. Those furnaces which have a relative deficiency of heat in the hearth and which generate, either actually or potentially, more heat in the shaft than they need. These furnaces do not in general superheat their iron and have a tendency to work cold in the bottom, the condition most favorable to preventing complete deoxidation and supercarburization. To this (Class II.) belong the coke furnace on lean or refractory ores and the cold-blast charcoal furnace.

The iron of Class II. made with either kind of fuel is superior in reputation and test to the iron of Class I. made with the same fuel, but charcoal iron has two vast advantages over the coke iron in both classes:

1. Because of the absence of any considerable amount of sulphur, which can mask or destroy the beneficial action of the oxygen.

2. Because the critical temperature is so much lower than that of a coke furnace under the best conditions, because the charcoal furnace does not suffer under the necessity of using the calcareous and relatively infusible slag necessary for desulphurization in coke practice. This gives charcoal iron the possibility of securing always a lower degree of carburization and a higher oxygen content than is possible with the coke furnace, but this possibility has in the past often been wasted because quality has been largely disregarded in Lake Superior charcoal iron until within the past three years.

Moreover, it is only as the result of the present investigation along two lines simultaneously, the complete chemical analysis of the different qualities of iron, particularly for carbon and oxygen, and the detailed investigation of the heat balances of different conditions of furnace operation, showing how these affect deoxidation and carburization, that it has been possible to reach these conclusions, which seem to me to reconcile practice and theory to a greater extent than has been possible hitherto. The possibilities which the discovery of these facts offers for improvement in the quality of charcoal iron will be seen to be enormous, and those who have used these irons for many years seem willing to admit that we have already effected much improvement.

In accordance with the two principles of not using an excessive blast temperature and of using an admixture of an ore even less reducible than our normal supply, we have been able to make irons of the chilling grades closely approaching "special cylinder" in quality

in the regular operation of the furnace and without having to await "a mess" to produce it. These irons we believe will equal the best that can be made at the Southern and Eastern furnaces, except those using cold blast.

The electric pig iron furnace furnishes an extreme case of a furnace running with an excess of heat in the hearth. Authoritative figures for the furnace at Trollhätta give its consumption of charcoal as about 800 lb. per ton, while the electric current consumed is equivalent to about 2,500 thermal units per pound of iron against 1,000 for a coke furnace making a much larger slag volume.

The characteristic of the electric furnace is that the temperature of application of its heat may just as easily be high as low. Nearly all the heat in these furnaces is generated in the hearth and the excess not needed there is carried up through the charge column by the gas, and only a slight amount is produced by additional oxidation by oxygen from the ore.

These conditions lead to enormous superheating of the iron and to consequent perfect reduction, in spite of the relatively small quantity of fuel present. The result of this complete deoxidation and of the excessive temperature at which these irons are made is a very high degree of carburization, a practically complete absence of combined carbon, excessive quantities of graphite and the latter extending in an almost continuous network through the iron.

This, in conjunction with its low combined carbon, makes it exceedingly weak. I am informed on the authority of S. T. Wellman that this iron as it comes from the furnace has a tensile strength of only about 18,000 lb.

In Figs. 25 and 26 are shown photomicrographs of electric furnace pig iron, etched and unetched, which are reproduced here from *Chemical and Metallurgical Engineering* through the courtesy of H. M. Boylston, of Boston.

These photomicrographs show the same characteristics as the poor charcoal irons, but in a more exaggerated degree.

This furnishes a complete confirmation of what has been said above concerning the furnace conditions under which good and bad irons are made.

HIGH vs. LOW CARBON

Just here it seems worth while to say a word concerning the relative merits of high carbon and low carbon, about which there has been no little dispute, and concerning which but little appears to be known further than that some customers insist on having high carbon

irrespective of anything else, whereas, others want the carbon as low as they can get it.

The difference appears to lie in the use to which the iron is put. If it is to be chilled, then the more carbon present the greater the percentage of cementite in the chilled portion and the harder the latter will be, other things being equal. The absence of a sufficient amount of carbon from chilled castings made with a large percentage of steel scrap may well be one of the causes for the poor reputation of such chilled castings as compared with those made with low-silicon charcoal irons.

If, on the other hand, a special iron be desired for strength and closeness of grain (but not chill), as in steam or gas engine cylinders, the higher the carbon the worse it makes matters, because the strongest mixture must be one containing approximately 1 per cent. of combined carbon, and the greater excess there is over this amount the greater will be the amount of graphite, with its tendency to gather into larger aggregates as its quantity increases, so diminishing both the strength and the tightness of the casting.

THE EFFECT OF OTHER ELEMENTS

During the course of our investigation the effect of various other elements besides oxygen was investigated also, and the results are believed to be worth recording here, though of less importance than those on oxygen.

Nitrogen

Analyses for this element by the customary method met with a difficulty which greatly delayed the investigation along this line. The hydrocarbons formed by the solution of the sample in hydrochloric acid passed over into the Nessler solution and gave it a milky, yellowish appearance, making comparison of the color with that of a similar tube containing pure ammonia impossible. This difficulty was finally overcome by adding potassium permanganate to the acid solution and boiling it for a considerable while, then overneutralizing with caustic soda and boiling further to drive over the ammonia. We found various quantities of ammonia, which, calculated back to nitrogen, amounted to about 0.01 per cent. as a maximum, with quite wide variations. Generally, the highest quantities were present in the irons made on the coldest furnace, but we seemed unable to get any definite relation between nitrogen and quality.

We then made twin remelts of various irons, as above described, using the same irons in both crucibles, but adding a considerable

quantity of potassium cyanide to one of the crucibles a short time before pouring. The effect on the chill block cast from these remelts was distinctly marked, increasing the chill and the fineness of the grain and giving a purplish appearance to the zone between the chill and the gray; but the strength of the bars was not materially affected, even by greater quantities of nitrogen than we had ever found in the iron from the furnace, and we reached the conclusion that the effect of nitrogen was not of much industrial importance in cast iron.

Cyanogen

It occurred to us that this compound might exist in the iron, as its presence in the hearth and bosh of the blast furnace has often been proved. We made analyses by several different methods which should have shown any cyanide if present, but with a purely negative result.

Phosphorus

Two twin remelts were made, as above described, using as a base in one case a spotted iron, in the other a special cylinder iron. To one crucible in each remelt was added enough ferro-phosphorus to raise the percentage of this element to about 0.6. The chill was markedly increased in the special cylinder iron, which is more notable in view of the normal high chill of these irons.

The iron was quite low in silicon, so that the chill block was chilled clear through in both cases, but the quality of the phosphorus chill was far better to the eye than that of the straight remelt. There was a marked reduction of the size of the crystals and a tendency to pass from the flat and crystalline to the conchoidal and smooth fracture. The strength was increased about 20 per cent. in the poor iron and about 5 per cent. in the good iron. The results are shown in Table III.

We find here again that remarkable relationship between high chill and strength upon which I have so frequently commented.

The obvious explanation is that the iron with a higher combined carbon is the stronger within wide limits, but that this does not tell the whole story in all cases is conclusively proved by the results of Table I. above cited.

In the case of phosphorus the ultimate reason for the effect is as little known to us as in the case of oxygen, but we may make a suggestion. The effect of phosphorus in increasing fluidity is so well known as to need no comment here. This presumably means lowering the freezing point of the last-freezing portion; that is, the eutec-

tic, in case the iron has a tendency to form a eutectic. Lowering the freezing point of this constituent would give a better opportunity for the first-freezing austenitic constituent to solidify and knit itself together so as to resist penetration by the plates of eutectic and to force the latter into small isolated pools of approximately equal dimensions in all directions; instead of permitting its formation into plates of great length and breadth, but little thickness.

It is easy to detect the presence of the phosphide eutectic in irons containing 0.50 per cent. or more of this element, and the structure of this eutectic, judging by its appearance, seems to be very different from that of the carbon eutectic. It is, in fact, very much more like pearlite. This also is probably an element of strength to the mass as a whole.

These hypotheses are not intended to be taken as statements of facts, but only as suggestions, which scientific investigators may attack at will and confirm or disprove according to the evidence.

I have previously mentioned the fact, first brought to my attention by R. W. Durrett, that phosphorus has a strong influence in reducing the total carbon of the iron. This may come from an effect similar to that of silicon in simply crowding out any excess, or it may be due to increased fluidity, which permits the iron to melt at a lower temperature and escape from the superheating and carbonization conditions above the tuyeres more quickly.

Chromium

Two twin remelts were made with chromium, using special cylinder iron, the same as No. 277, as a base. In one case there was added to one of the crucibles enough chromium to raise the percentage of this element to 2.18 per cent.; in the other to 4.00 per cent. The results are given in Table IV. It will be seen that the strength is but slightly increased over that of the same iron untreated, while the combined carbon is very materially increased, as shown by the chill and by the fracture of the bars. The chill, of course, was increased also, but not to the extent we had expected with these percentages. An interesting fact is that the fractures of the test bars showed under the microscope the eutectic structure so fully illustrated last year in connection with spotted and high cleavage iron, as shown by Fig. 27. This may be compared with Fig. 14, although the original iron of the chromium remelt was considerably better iron than that of Fig. 14; incidentally, the oxygen was also much higher.

We secured for examination a pig of an iron now being recommended

for its chill and strengthening qualities on account of its chromium content, and were struck at first glance by the presence of a white spot in the center of the pig. We accordingly made a photograph of the iron from an edge of this pig, which is shown in Fig. 28. Beside it, Fig. 29, is reproduced Fig. 5 from my paper of last year. The conclusion seems irresistible that while chromium throws carbon into the combined condition and therefore increases the strength within certain limits, it also causes the formation of a eutectic similar to, if not identical with, that which forms in high-carbon irons. Reasoning by analogy, as well as by results from the test bars, with their relatively insignificant increase in strength for a very considerable increase in combined carbon, we seem justified in believing that while chill and some strength may be secured by the addition of chromium, it will never be possible to obtain simultaneously by this means all the qualities for which the better grades of charcoal iron are in demand. These qualities we now attribute to their high content of oxygen; the high temperature and strong deoxidizing conditions necessary for the reduction of chromium are, to say the least, unfavorable to the simultaneous presence of this element and of oxygen.

Manganese

By a fortunate chance we have had to make for commercial reasons two or three runs on an iron of much higher manganese than common; in one case going up to standard spiegel. On each occasion when the manganese has risen somewhat beyond 1 per cent. we have been able to perceive at once in the chill blocks and test bars made from the cast an increase in chill and an increase in strength, but the chill is of the high-cleavage variety and is accompanied by high carbon, as is well understood in the case of spiegel. An examination of the shining plates of spiegeleisen ("looking-glass iron") will show those interested the high-cleavage structure to which I have so often alluded; in fact, on the broken ends of some pigs of this material plates scarcely thicker than a sheet of writing paper and almost as large as one's thumb nail may be seen sticking out from the body of the iron. These we take to be the eutectic of iron, manganese, and carbon, exactly similar to those already described for high carbon and for chromiferous irons.

REASON FOR POOR QUALITY OF MANGANESE AND CHROME CHILLS.

It seems likely that this characteristic structure may account for the poor wear give in service by chilled objects made with ordinary irons and ferro-manganese or ferro-chrome additions.

In car wheels it is well understood that the strength and chill prescribed by the Master Car Builders can be obtained by this means, but it is also a matter of sorrowful knowledge to the railroads that these wheels will not give the wear in service obtainable from wheels made of good charcoal iron, and that shelling out is their great weakness. Their structure is fundamentally one composed of these flat plates massed together, but not interlaced, because they seldom penetrate one another. It is natural that under the combined stresses of temperature due to braking and the rolling stress due to moving contact with the rail, separation should occur along these cleavage planes at points some little distance removed from one another, and that these cleavages should eventually come to form the boundaries of a section of tread, which becoming more and more loosened finally becomes detached altogether, causing a shell-out.

The same thing applies to the surface of chilled rolls but not to the same extent, because the intensity of stress per unit of area is less severe.

CONCLUSIONS

1. Irons which contain oxygen to a considerable extent, in a form as yet unknown, are stronger and tougher and have better chilling qualities than irons containing less of this element, but of the same analysis in other respects.

2. Irons may contain a sufficient quantity of carbon to make them rotten and worthless through the predominance of the eutectic structure when deficient in oxygen, and yet, when they contain a considerable quantity of oxygen, be entirely free from this structure and of excellent quality.

3. Furnace conditions control whether the carbon shall be below or above the eutectic ratio and the presence of much or little oxygen, the two dominant factors in the fundamental quality of the iron; that iron, broadly, being the best which is made at the lowest temperature.

4. Charcoal irons can be made at temperatures several hundred degrees lower than are practicable with coke and have a great possible advantage in that respect. This is largely wasted without good furnace work in the broadest sense.

5. Phosphorus up to 0.50 per cent. or more exercises a beneficial influence on the strength of the iron and the depth and character of the chill. Phosphorus also has a tendency to reduce total carbon.

6. Aluminum and titanium tend to reduce the strength and chilling power of the iron by removing its oxygen, but titanium may have an influence independent of this on account of its removing nitrogen also.

7. Chromium and manganese have an almost identical effect in raising the total carbon and throwing it into the combined condition. The latter increases the chill and the strength, but the combined carbon so produced is in the form of eutectic plates, which deprive the iron of much of the strength which it would have with the same combined carbon in the absence of these plates.

8. Chill produced by these elements cannot be expected to have the same wearing qualities as that produced by elements which do not further the formation of flat plates of eutectic.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the New York meeting, February, 1914, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close April 1, 1914. Any discussion offered thereafter should preferably be in the form of a new paper.

The Injection of Cement Grout into Water-Bearing Fissures

BY FRANCIS DONALDSON,* NEW YORK, N. Y.

(New York Meeting, February, 1914)

THE direct injection of cement grout into water-bearing fissures as a means of checking or stopping the flow of water into shafts and tunnels has been experimented with for a decade or longer and seems to have been first attempted in Europe. The earliest application of which the writer has found a record was at a shaft sunk by the Mining Society of Lens; this is described by C. Dinoire in the *Transactions of the Institution of Mining Engineers*.¹

It is only lately, however, that the process has been entirely successful. This success has been accomplished on the Catskill Aqueduct, now under construction by the city of New York. This aqueduct includes a number of deep pressure tunnels, reached by shafts for both waterway and construction purposes. In portions of these shafts and tunnels considerable underground water was met. The contract for the first of these deep pressure tunnels was let to the T. A. Gillespie Co.; this section is known as the Rondout Siphon. It leads under the Rondout valley at a depth of from 400 to 800 ft. and is about 5 miles long. The engineers expected that considerable water would be encountered, but fortunately this was not the case except at one shaft, known as No. 4, which penetrated the rock at a junction between limestone and conglomerate. Water-bearing fissures were encountered almost immediately. At a depth of about 200 ft. a flow of 1,500 gal. per minute was struck. The shaft then contained as many pumps as could be used, and it seemed impossible to sink it further. After vain efforts had been made to proceed, John P. Hogan, a division engineer of the Board of Water Supply, suggested that cementation of the fissures be tried. The process was attempted for the first time in this country. Since the shaft was partly full of water it was necessary to drill grout holes with a diamond drill. Platforms were placed on the timbers at the water level, the diamond drill was installed and six 90-ft. holes were drilled in the bottom of the shaft. Several car loads of cement were pumped through these holes into the fissures, the drill casings being used for grout pipes. This largely cut off the flow of water from the bottom and sinking could then

* Non-member.

¹ Vol. xxxi, pp. 113 to 122 (1905-06).

proceed. After that, water-bearing seams were grouted as soon as encountered, and the contractor was able to finish the shafts and tunnel within the contract time. Shaft No. 4 was a rectangular, timbered construction shaft with no concrete lining; consequently it was impossible to cut off any of the water coming in from above the point where grouting was first attempted. On this account large volumes of water had to be pumped until the tunnel was finally sealed.

At the next wet shaft the writer had to do with, advantage was taken of the experience gained at shaft No. 4. At this second shaft, No. 4 of the New York City Siphon, good progress was made until a depth of about 100 ft. was reached. The first hole drilled in the bottom below this depth struck a stream of water; the flow amounted to about 150 gal. per minute. This was plugged. It was found that each of the 12 holes in the sump cut encountered the same stream of water.

As soon as each hole cut the water-bearing seam it was plugged with a tapered wooden plug. After all the holes in the sump had been drilled and plugged in this way, the grout connections were made one at a time, so as to restrict the flow of water into the shaft. Each connection was made with a piece of 2- or 2.5-in. iron pipe about 3 ft. long, threaded at one end and given a long taper at the other. The tapered portion was made rough on the outside by nicking it with a chisel. A heavy iron stopcock was screwed to the pipe, the tapered end wrapped in several thicknesses of burlap, the wooden plug removed from the drill hole and the tapered pipe driven in, the stopcock being left open. This was the most exciting and the wettest part of the job. After the pipe had been driven in hard the stopcock was closed.

In this case connections were placed in all the wet holes before grouting. The grouting machine or tank used on the aqueduct was the Caniff machine, in which the grout is mixed by air. It is built like an air lock with a door on the top through which cement, sand, and water are introduced, and has a 2-in. discharge opening in the bottom and air connections top and bottom. The discharge opening is connected to the grout hole by a heavy rubber hose. Another 2-in. stopcock is placed at the outlet of the tank and a 2- by 1-in. tee is placed between the hose and the cock attached to the pipe in the drill hole. Into the side opening of this tee a 1-in. stopcock is screwed.

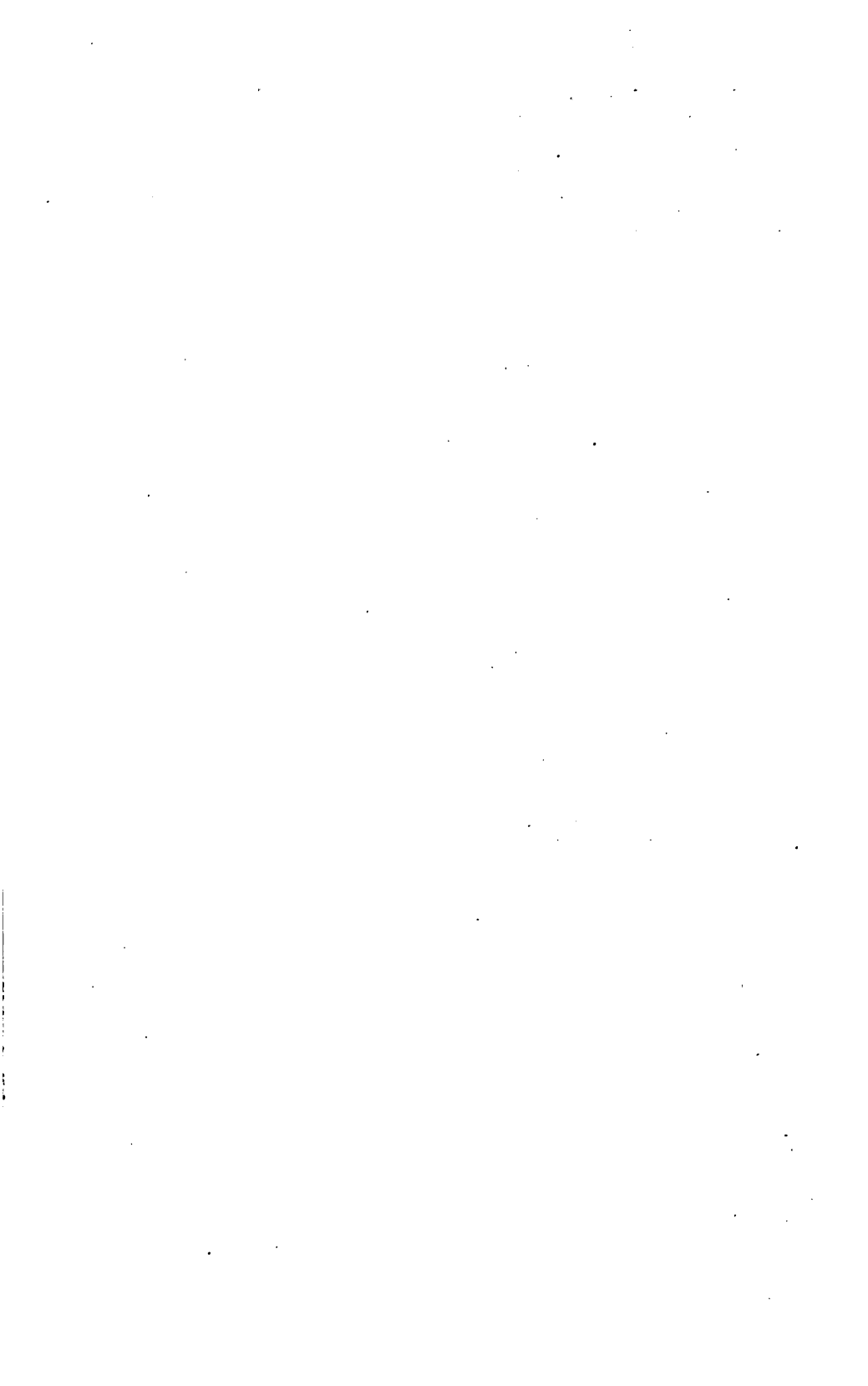
The machine is installed at the bottom of the shaft, and is connected to one of the holes and also to the high-pressure air supply. The 2-in. stopcock on the machine is closed and the other is opened. The door in the top is opened, a sack of cement, three or four buckets of water, and (if the cavity to be filled is large) a sack of fine sand are poured in, the air connection at the bottom is opened and the air allowed to bubble through and mix the grout. Then very quickly the door is closed, the lower air connection is closed, and the discharge connection and the

upper air connection are opened, and the air enters and drives the grout into the cavity. A man stationed at the 1-in. stopcock keeps opening it a crack; when air shows instead of grout he closes the 2-in. stopcock and the machine is recharged. If the cavity is open the charge is pushed in in 3 or 4 sec. By working continuously more than 1,000 batches can be placed in 24 hr.

The grouting of the fissure was successful and sinking was resumed. About 50 ft. further down another water-bearing fissure was drilled into, and this, instead of being open, was filled with sand formed by the crushing of metamorphic gneiss due to folding; this sand was carried up out of the drilled holes in large quantities by the water. Grout will not permeate sand and it was necessary to continue drilling holes and pumping in grout, increasing the pressure at the end from 100 to 400 and 500 lb. to the square inch. The sand was tamped so full of cement that when cut through it was compacted like sandstone and contained balls of grout from the size of a fist to as large as a man's head.

The most difficult grouting on the aqueduct was done on the Hudson Siphon, which is a deep siphon tunnel under the Hudson river at a depth of 1,100 ft. below tidewater. The shafts were sunk by the city forces, after which the contract for the driving and lining of the tunnel and lining the shafts was let. About 150 ft. from the foot of the east shaft the heading cut a water-bearing fissure which flowed about 300 gal. per minute. The full flow did not develop until the cut was blasted. The problem then was to grout this flow against a hydrostatic pressure of 500 lb. per square inch, with no solid rock to which to make grout-pipe connections. This problem was finally solved by the construction of a concrete bulkhead 8 ft. thick across the full section of the head. The concrete was mixed in proportions of 1:2:4 and was heavily reinforced with rails set into holes drilled laterally into the sides, roof, and floor of the tunnel. Grout pipes leading into the fissure were set through the bulkhead. After the concrete had set for a week, grout was forced into the fissure, first by the pneumatic process with a high-pressure air compressor and finally by means of a high-pressure plunger pump which forced water instead of air into the grout tank. Pressures were reached in this way up to 1,000 lb. per square inch.

In driving or sinking through rock containing a large number of seams carrying small quantities of water, it is not practicable to stop and grout each seam as described above. In this case it is advisable to increase the section of tunnel or shaft sufficiently to allow for a heavy concrete lining. Drains should be provided opposite all of the water-bearing fissures to carry off the water while the lining is being placed. After the concrete has secured sufficient strength, the drains may be grouted. By a combination of these two methods it should be possible to penetrate any firm rock, no matter how much water it contains.



DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the New York meeting, February, 1914, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 20 West 29th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Apr. 1, 1914. Any discussion offered thereafter should preferably be in the form of a new paper.

The Equilibrium Diagram of the System $\text{Cu}_2\text{S}-\text{Ni}_3\text{S}_2$

BY CARLE E. HAYWARD, BOSTON, MASS.

(New York Meeting, February, 1914)

THIS work was first undertaken in the metallurgical laboratory of the Massachusetts Institute of Technology in 1907 by L. A. Dickinson, E. Phelps, and V. S. Rood, under the author's direction. They attempted to determine the diagram for the system $\text{Cu}_2\text{S}-\text{NiS}$, but several inexplicable results were obtained. The following year, P. H. Mayer with Mr. Dickinson carried on some experiments with nickel sulphide and found that the molten material slowly lost sulphur until it reached a composition corresponding to the compound Ni_3S_2 , established by Bornemann.¹ At this point the composition remained stable. The freezing points of the mixtures gradually fell off with the loss of sulphur.

Since the above facts seemed to explain the erratic results obtained in the first experiments, Mr. Mayer with F. Jaeger attempted in 1910 to establish a correct equilibrium diagram for the $\text{Cu}_2\text{S}-\text{Ni}_3\text{S}_2$ series. They prepared pure Cu_2S and Ni_3S_2 and determined the cooling curves for various mixtures. The fusions were made in a platinum resistance furnace and the temperatures were measured with a platinum-iridium thermocouple connected with a Sullivan galvanometer. The curve was established for mixtures containing more than 40 per cent. Cu_2S , but they were unable to determine certainly the direction of the curve beyond that point.

Nothing further was attempted with this series until the present year, when the work was carried to a successful conclusion with the assistance of A. Butts, Jr., and E. H. Weil. The results of this work are given in the following pages.

Preparation of Cu_2S .—A piece of cathode copper from the Buffalo plant of the Calumet & Hecla Co. was cut into shavings by a shaper and converted into sulphide by heating in boiling sulphur. A porcelain casserole was used for the purpose, the heat being furnished by a Bunsen burner. It was found that after boiling in the sulphur for an hour the copper shavings were completely converted into sulphide. The liquid sulphur was then poured off, leaving the solid sulphide in the casserole in

¹ *Metallurgie*, vol. v, No. 1, p. 13 (Jan. 8, 1908).

the form of a porous mass, each particle of which retained in general the shape of the copper shaving from which it was formed.

When cold, the sulphide was removed from the casserole, broken into small pieces, mixed with 15 per cent. of its weight of flowers of sulphur and melted in a graphite crucible under a cover of charcoal. The sulphide was kept in a molten condition for 5 hr. and then allowed to cool in the crucible.

The analysis of the material thus obtained was: Cu, 79.18; S, 20.24;

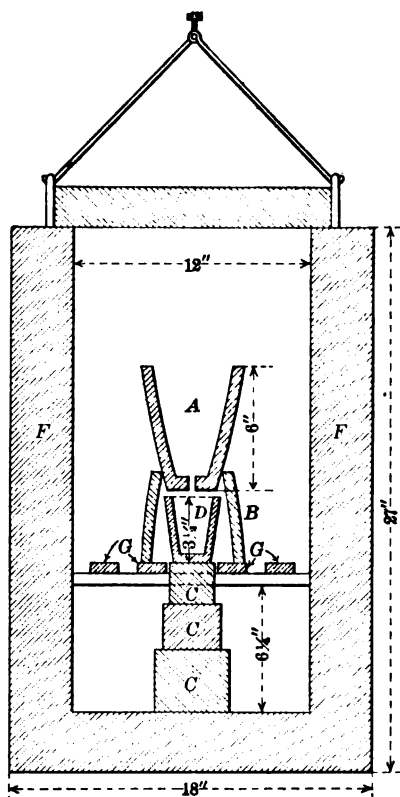


FIG. 1.—POT FURNACE.

Fe, 0.43; insoluble, 0.24; total, 100.09 per cent. The composition, calculated from the above analysis, was as follows: Cu_2S , 99.13; FeS , 0.68; SiO_2 , 0.24; total, 100.05 per cent.

Preparation of Ni_3S_2 .—The Ni_3S_2 was prepared from sulphur and electrolytic nickel. The latter was furnished by the International Nickel Co., and the analysis as given by them was: Ni, 98.90; Co, 0.9; Fe, 0.14; Cu, 0.02; total 99.96. Since the behavior of Co is very similar to that of Ni, there will be little error if the small amount present is included with the Ni.

The apparatus used for preparing the sulphide is shown in Fig. 1. *F* represents the walls of one of the laboratory pot-furnaces with grate bars *G*. A size K Battersea crucible was cut off about 2 in. from the bottom and placed as shown at *B*. A second crucible of the same size, with

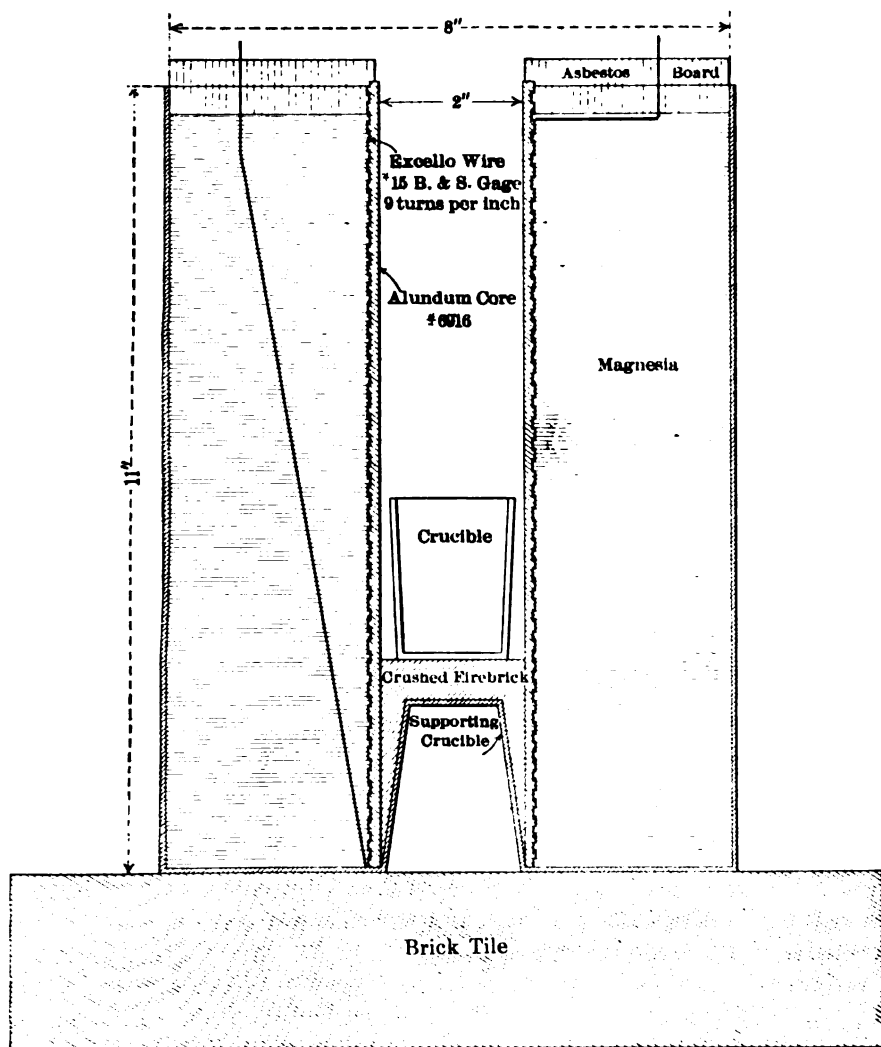


FIG. 2.—ELECTRIC FURNACE.

a 0.5-in. hole drilled through the bottom, was placed as shown at *A*. Bricks were placed below the grate bars as shown at *C* in order to support a "Denver B" crucible as shown at *D*.

A coke fire was built on the grate around the crucibles *A* and *B*. The nickel cathode was cut into strips by power shears and these strips were

placed in the crucible A. When a temperature of about $1,000^\circ$ was attained the cover of the crucible was removed, some stick sulphur thrown in and the cover replaced. Some nickel sulphide was formed and flowed out through the hole in the bottom of crucible A into crucible D. This procedure was repeated at short intervals until practically all the metallic nickel was converted to sulphide.

The crucibles were next removed from the furnace. When cool, the sulphide was removed, broken to pea size, mixed with about 15 per cent. of its weight of sulphur and remelted in a graphite crucible. The crucible containing the sulphide was set in a larger crucible and the space between filled with charcoal, in order to assure a reducing atmosphere. When the sulphide was melted, it was covered with charcoal and kept at about

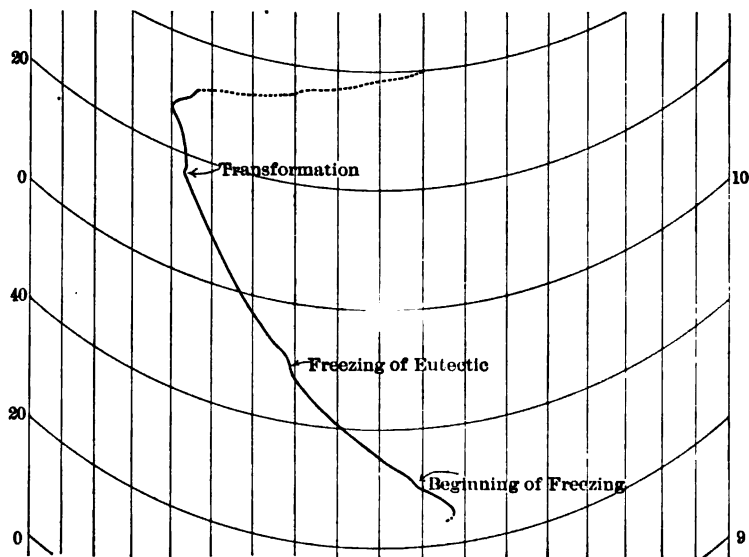


FIG. 3.—COOLING CURVE FOR 50 Cu_2S , 50 Ni_3S_2 .

$1,000^\circ \text{C}$. for 35 hr. in periods of about 8 or 9 hr. each. There was no reason for heating intermittently, but the coke fire was allowed to burn out over night.

After 12 hr. of fusion the material contained 69.87 per cent. Ni; after 20 hr., 72.25 per cent. Ni. The final product had the following composition: Ni(Co), 72.45; Fe, 0.53; insoluble (SiO_2), 0.30; S (by difference) 26.72 per cent. The rational analysis of the sulphide calculated on the above basis is therefore

$\text{Ni}_3\text{S}_2(\text{Co}_3\text{S}_2)$	98.87
FeS.....	0.83
Insoluble.....	0.30
Total.....	100.00

Furnace.—The sketch of the furnace used for determining the cooling curves is shown in Fig. 2 and is self-explanatory. It was connected to the 110-volt circuit in series with two rheostats for controlling the temperature. A current of 10 amperes was sufficient to produce a temperature of $1,200^\circ \text{C.}$ in 30 min.

Pyrometer.—The temperatures were measured by a Pt-Pt.Rh couple connected to a Siemens & Halske recording galvanometer. This instrument draws a cooling curve consisting of a series of dots imprinted by a pointer attached to the galvanometer needle as it is automatically pressed every 15 sec. on a paper moved by clock work over an inked ribbon. Fig. 3 shows a typical curve made by this instrument.

The pyrometer was calibrated in the usual manner with the cold junction in a bath of melting ice. The following results were obtained:

	Temperature. Degrees C.	Deflection. Millivolts.
Melting point of ice.....	0	0.00
Boiling point of water.....	100	0.40
Boiling point of naphthalene.....	218	1.20
Boiling point of sulphur.....	444	3.33
Freezing point of aluminum.....	657	6.02
Freezing point of sodium chloride.....	800	8.02
Freezing point of silver.....	961.5	10.57
Freezing point of copper.....	1,084	12.72

Determination of Cooling Curves.—Charges weighing 60 g. were used in all cases except where only a slight retardation point was indicated, in which instances 100-g. charges were used. The fusions were made in No. 00 graphite crucibles with a charcoal covering to prevent oxidation of the charge. The junction was protected by a fused silica tube. In order to be certain that the entire charge was melted it was found necessary to heat each test above $1,100^\circ$. Two cooling curves and one heating curve were obtained for each mixture, and in cases where points were in doubt three or more were obtained.

In nearly all cases the instrument recorded sharply the beginning of freezing and the other retardation points. These deflections were carefully scaled on the record paper and the corresponding temperatures obtained from the calibration plot. The results are given in the following table:

Per Cent. $\text{Cu}_2\text{S.}$	Per Cent. $\text{Ni}_3\text{S}_2.$	Recorded Retardations. Degrees Centigrade.	
100.0	0.0	1,130	
97.5	2.5	1,086	
95.0	5.0	1,068	
90.0	10.0	1,043	727
80.0	20.0	1,008	728
70.0	30.0	982	731

Per Cent. Cu_2S .	Per Cent. Ni_3S_2 .	Recorded Retardations. Degrees Centigrade.	
60.0	40.0	953	731
50.0	50.0	925	729
40.0	60.0	884	728
30.0	70.0		727
30.0a	70.0	820	726
27.5a	72.5	798	726
25.0a	75.0	773	728
20.0	80.0	727	
20.0a	80.0	726	
10.0	90.0	739	(728)b
5.0a	95.0	768	(740)b
0.0	100.0	794	

a 100-gram charge.

b End of freezing.

In none of the tests recorded above was the record taken below 600° . When the work was nearly completed, however, it was recalled that Bornemann² had recorded a transformation in Ni_3S_2 between 527° and 538° . The cooling curves for the samples with 100, 75, 50, 10, and 2.5

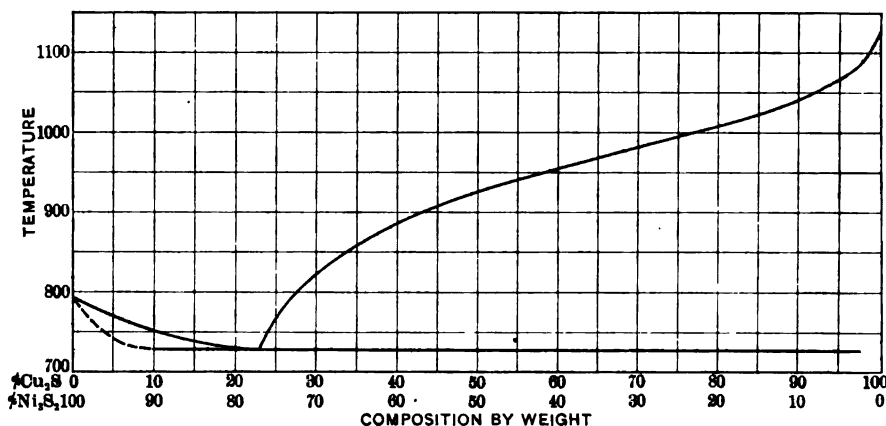


FIG. 4.—EQUILIBRIUM DIAGRAM OF THE SYSTEM $\text{Cu}_2\text{S}-\text{Ni}_3\text{S}_2$.

per cent. of Ni_3S_2 were therefore re-determined and a lower point was found at 546° , 532° , 532° , 531° , and 525° , respectively. This seems to indicate that it is probably present in the other mixtures.

Equilibrium Diagram.—The equilibrium diagram plotted from the above figures is shown in Fig. 4. It is of the typical underscored-V type and is self-explanatory. The position of the eutectic point and the ends of the eutectic line were established by further tests, as described later.

Photomicrographs.—After determining each cooling curve, a piece of

² *Metallurgie*, vol. v, No. 1, p. 13 (Jan. 8, 1908); vol. vii, No. 21, p. 667 (Nov. 8, 1910).



FIG. 5.— Ni_3S_2 .



FIG. 6.—5 Cu_2S , 95 Ni_3S_2 .

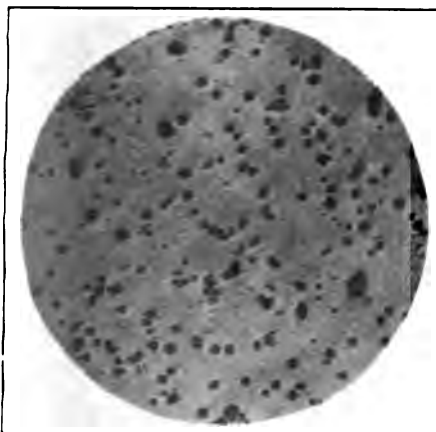


FIG. 7.—10 Cu_2S , 90 Ni_3S_2 .

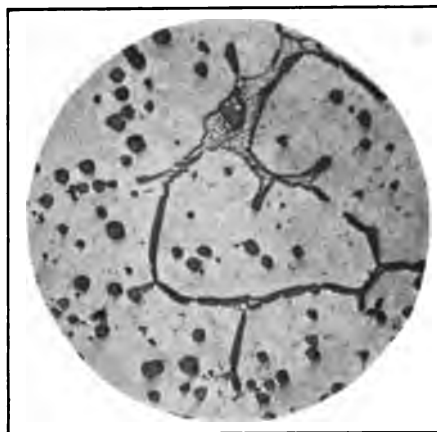


FIG. 8.—15 Cu_2S , 85 Ni_3S_2 .

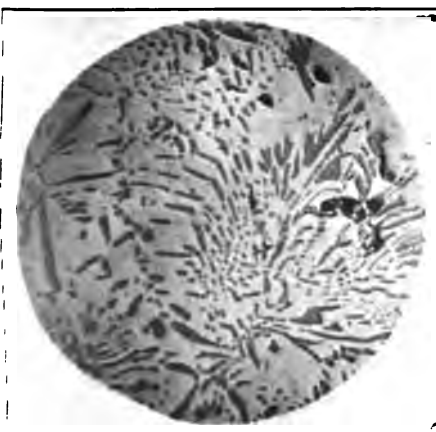


FIG. 9.—20 Cu_2S , 80 Ni_3S_2 .

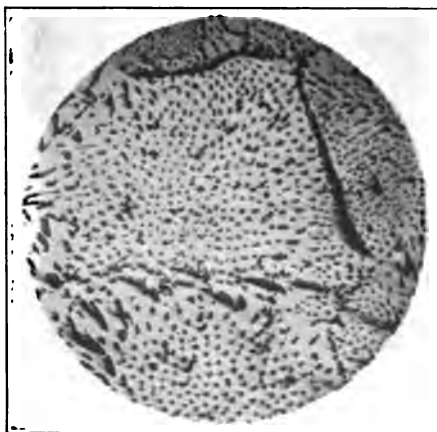


FIG. 10.—23 Cu_2S , 77 Ni_3S_2 .

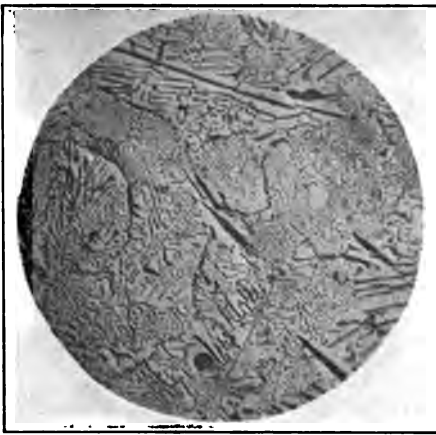


FIG. 11.—EUTECTIC RAPIDLY COOLED BUT NOT CHILLED.



FIG. 12.—25 Cu_2S , 75 Ni_3S_2 .

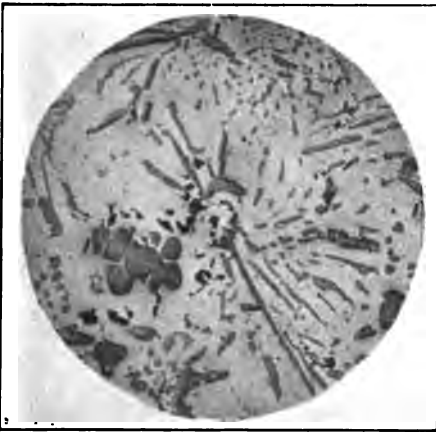


FIG. 13.—30 Cu_2S , 70 Ni_3S_2 .

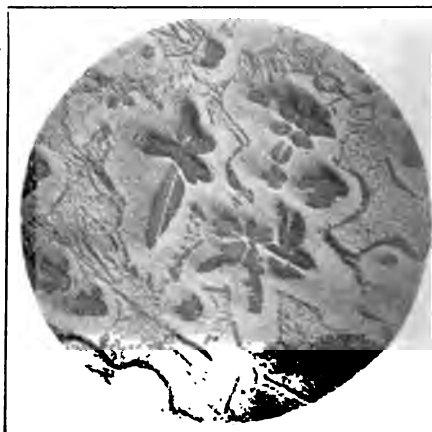
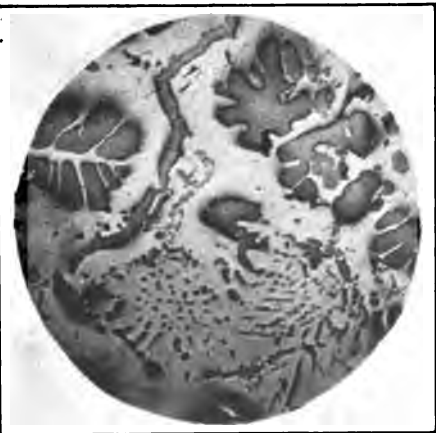


FIG. 14.—30 Cu_2S , 70 Ni_3S_2 . COOLED RAPIDLY BUT NOT CHILLED.



[FIG. 15.—40 Cu_2S , 60 Ni_3S_2 .

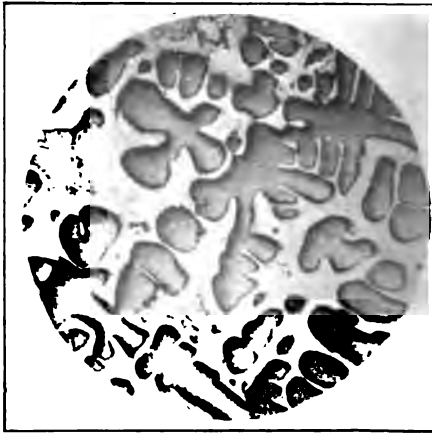


FIG. 16.—50 Cu_2S , 50 Ni_3S_2 .

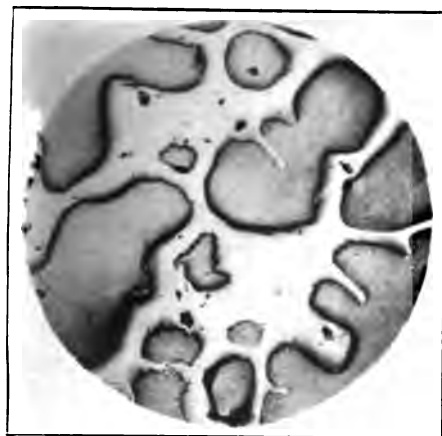


FIG. 17.—60 Cu_2S , 40 Ni_3S_2 .

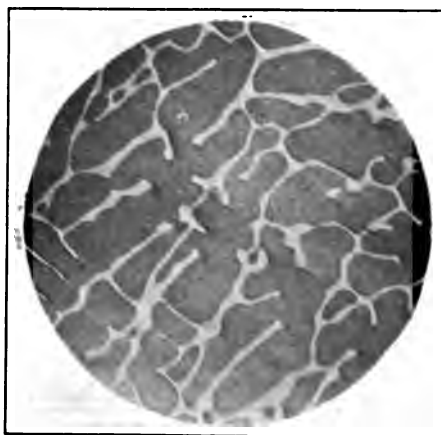


FIG. 18.—70 Cu_2S , 30 Ni_3S_2 .

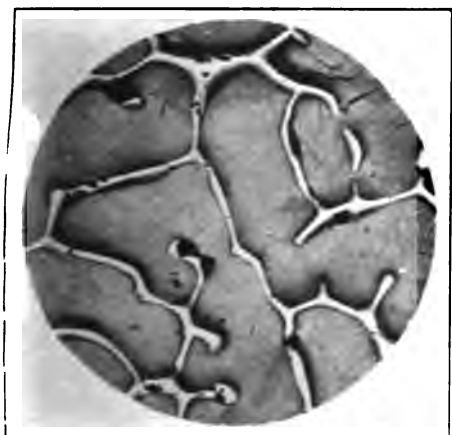


FIG. 19.—80 Cu_2S , 20 Ni_3S_2 .



FIG. 20.—90 Cu_2S , 10 Ni_3S_2 .



FIG. 21.—95 Cu_2S , 5 Ni_3S_2 .



FIG. 22.—97.5 Cu_2S , 2.5 Ni_3S_2 .

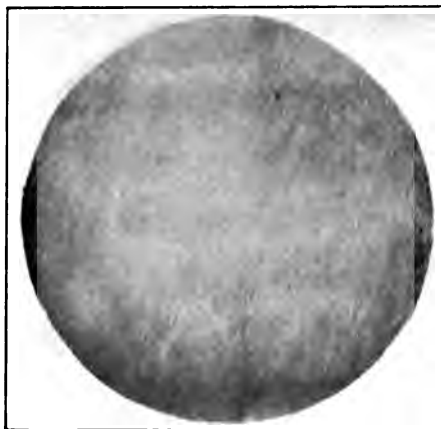


FIG. 23.— Cu_2S .

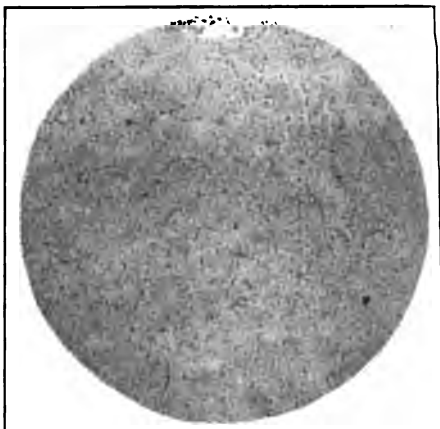


FIG. 24.—10 Cu_2S , 90 Ni_3S_2 . CHILLED.

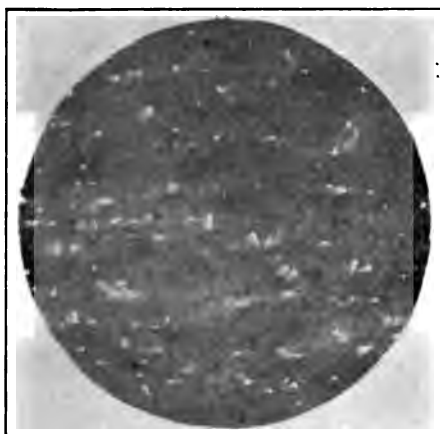


FIG. 25.—20 Cu_2S , 80 Ni_3S_2 . CHILLED.

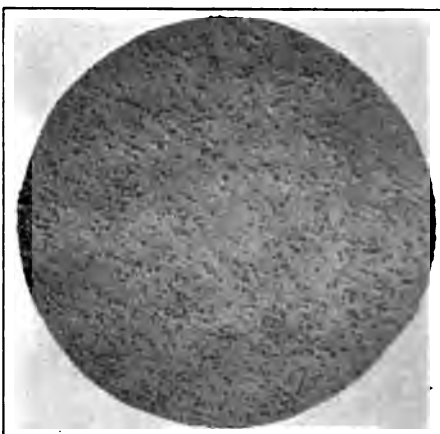


FIG. 26.—20 Cu_2S , 80 Ni_3S_2 . CHILLED, REHEATED.

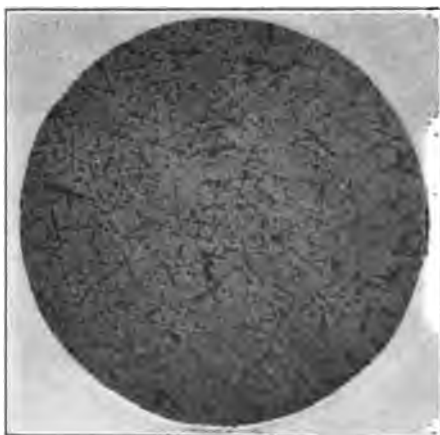


FIG. 27.—30 Cu_2S , 70 Ni_3S_2 . CHILLED.

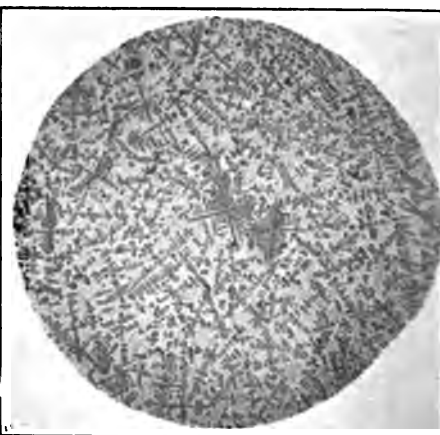


FIG. 28.—40 Cu_2S , 60 Ni_3S_2 . CHILLED.

the matte was polished and studied under the microscope. In the unetched specimens two constituents were observed, one pale brass and the other pale blue color. The former appears light gray in the photograph and the latter dark gray. These two constituents resemble in general pure Ni_3S_2 and pure Cu_2S , respectively, but are slightly darker in each case. It is probable that the lighter constituent is Ni_3S_2 with a small amount of Cu_2S in solution and that the darker constituent is Cu_2S with a small amount of Ni_3S_2 in solution. Actual measurements of the light and dark areas were made on several photographs, and, although check results were not obtained, it was found that they were roughly proportional to the amounts of Ni_3S_2 and Cu_2S in the sample. In the following discussion the light, or nickel-rich, constituent will be designated as α and the dark, or copper-rich, constituent will be designated as β . Etching with concentrated and dilute acids resolved the large β areas into grains, but failed to reveal anything further. Photomicrographs of the unetched specimens, magnified in all cases 60 diameters, are given in Figs. 5 to 28. A study of the series shows a eutectic structure beginning with 15 per cent. Cu_2S , becoming more marked with 20 per cent. Cu_2S , reaching a maximum with 23 per cent. Cu_2S , and then diminishing. In the photographs of specimens containing more than 60 per cent. Cu_2S the eutectic structure has disappeared. The cooling curves, however, showed a pronounced retardation at the eutectic line, so it is probable that the typical eutectic structure has been obliterated by segregation of the constituents. This segregation is not surprising in view of the wide difference in temperature between the point where freezing begins and the eutectic line.

Some of the photographs show irregular black spots due to cracks or pits in the specimens.

Special Tests.—The mixture containing 20 per cent. Cu_2S , as seen in the table, gave only one retardation point, which was at the eutectic line. The microscopic examination, however, indicated a slight excess of Ni_3S_2 , so a mixture with 23 per cent. Cu_2S was prepared, which, as seen in the photograph, is practically all eutectic. The eutectic point is accordingly placed at this composition.

The specimen with 10 per cent. Cu_2S showed no retardation at the eutectic line, but the photograph shows dots of β . In order to see if this β had separated in the solid state, the sample was remelted and the crucible was set in ice water just after the eutectic temperature was passed in cooling. The photograph of a polished section is shown in Fig. 24. Fine dots of β are seen, but the general appearance of the photograph indicates that a more rapid chilling of the specimen would have prevented the separation.

Since, therefore, the sample with 15 per cent. Cu_2S shows eutectic and the sample with 10 per cent. Cu_2S , as shown above, is probably a solid

solution when freezing is completed, the limit of the eutectic line falls between these two compositions. In the diagram it is drawn nearly to 10 per cent. Cu_2S , which is approximately correct. The opposite end of the eutectic line was fixed at 97.5 per cent. Cu_2S by a similar experiment.

Fig. 25 shows the structure of a chilled specimen of the matte with 20 per cent. Cu_2S . While the matte was still molten the crucible was removed from the furnace and the contents were poured into an iron mold. Fig. 26 shows the structure of the same specimen after annealing at 650°C . for a few minutes and cooling slowly. This specimen shows clearly the β crystals which have formed in the solid matte. Figs. 27 and 28 show respectively the structure of the matte with 30 and 40 per cent. Cu_2S , cast in an iron mold. It indicates that the β constituent originally forms as small dendrites and that the characteristic coarse structure of the slowly cooled specimens is due to the growth and segregation of these crystals.

Several tests were made to see if there was any tendency toward layering while the matte was liquid. For this purpose a 0.5-in. hole 5 in. deep was bored in a section of a 1-in. graphite rod, thus making a tall, narrow crucible. The matte was melted in this and held for 2 hr. in a molten condition (800°), after which it was cooled in the furnace and sections near the top and bottom were examined under the microscope. In all cases there was slightly more eutectic visible in the lower section, but this was probably due to the fact that the eutectic had melted first and flowed to the bottom.

A series of specific gravity tests was planned, but was abandoned because it was discovered that the specific gravities of the two sulphides were very nearly the same. The values were approximately: Cu_2S , 5.76; Ni_3S_2 , 5.84.

SUMMARY.

The results of this work may be summarized as follows:

1. Nickel sulphide of approximately the composition NiS when molten, gradually loses S until the composition Ni_3S_2 is reached, at which point it remains stable. This confirms the work of Bornemann.
2. The series $\text{Ni}_3\text{S}_2-\text{Cu}_2\text{S}$ is eutectiferous between 2.5 and 90 per cent. Ni_3S_2 . Outside of these ranges there is a series of solid solutions.
3. The eutectic point was found at 77 per cent. Ni_3S_2 .
4. The freezing point of Ni_3S_2 was found to be 794°C .; Cu_2S , $1,130^\circ\text{C}$.; and the eutectic, 728°C .
5. No evidence of chemical compounds between the two sulphides was discovered.

TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS
[SUBJECT TO REVISION]

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the New York meeting, February, 1914, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Apr. 1, 1914. Any discussion offered thereafter should preferably be in the form of a new paper.

The Geology and Ore Deposits of the Bully Hill Mining District, California*

BY A. C. BOYLE, JR., LARAMIE, WYO.

(New York Meeting, February, 1914)

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* Submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, in the Faculty of Pure Science, Columbia University, December, 1913.

I. INTRODUCTION

THE geological field work of the Bully Hill district, upon which this paper is based, was begun July 1, 1908, and covered a period of three months. The time was found too short for a complete report and the district was again visited in the early part of July, 1912, from which time detailed study of the locality continued until September of the same year. This paper is the result of observations made in the mines in the immediate vicinity of Winthrop, Shasta county, Cal., during these two periods of study.

The preparation of this report has been greatly facilitated by various courtesies rendered the writer by D. M. Riordan, President of the Bully Hill Copper Mining & Smelting Co., and by John B. Keating and Herbert R. Hanley, managing officers actively in charge at the mines. The elaboration and further study of the notes and collections were carried on in the laboratories of the Departments of Geology and Mining at Columbia University, and the writer takes pleasure also at this point in expressing his acknowledgments to Profs. James F. Kemp, A. W. Grabau, Charles P. Berkey, and William Campbell, for advice and assistance.

In order that one may appreciate at first reading the significance of some of the details which follow, and for the sake of clearness, a brief outline of the geological relationships is here given, together with certain conclusions which have been reached regarding the genesis of the ores and the gypsum masses.

In the Bully Hill mining district an associated series of Triassic lavas and tuffs, chiefly andesites, is preceded as well as followed by sediments. The entire system is tilted so that the original bedding planes dip in general to the southeast. The surrounding region has been greatly disturbed, and in the immediate vicinity of the mines close folding of the later sediments and extreme shearing of the igneous rocks locally is a striking feature.

Into the nearly vertical shear zones have been intruded post-Triassic dikes of various rock types in the following order: alaskite-porphyry and andesite-porphyry. Outside the area under consideration diorite dikes are known, but they will not receive attention further than to note that they probably represent a differentiation product of the same magma from which the other two dikes came. In this connection all the dikes have an important bearing on the origin of the ores and of the gypsum found in the mines.

The intrusion of the alaskite-porphyry as well as the later andesite was accompanied by the emission of magmatic waters and metal-bearing solutions. As these solutions passed upward they wrought important changes in the rocks within their influence, and were directly responsible for the introduction of the various ore minerals, as well as some of the

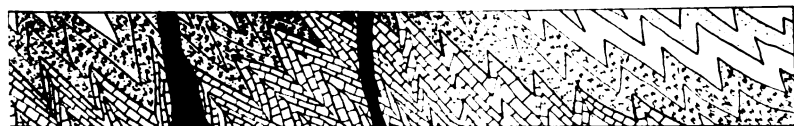
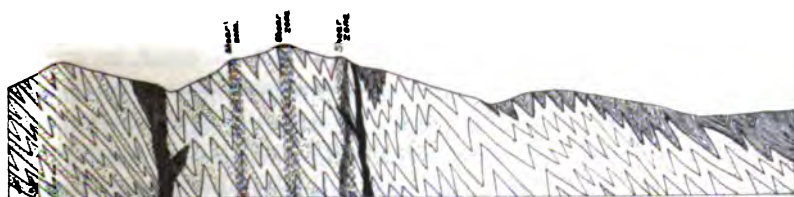
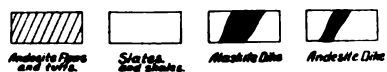
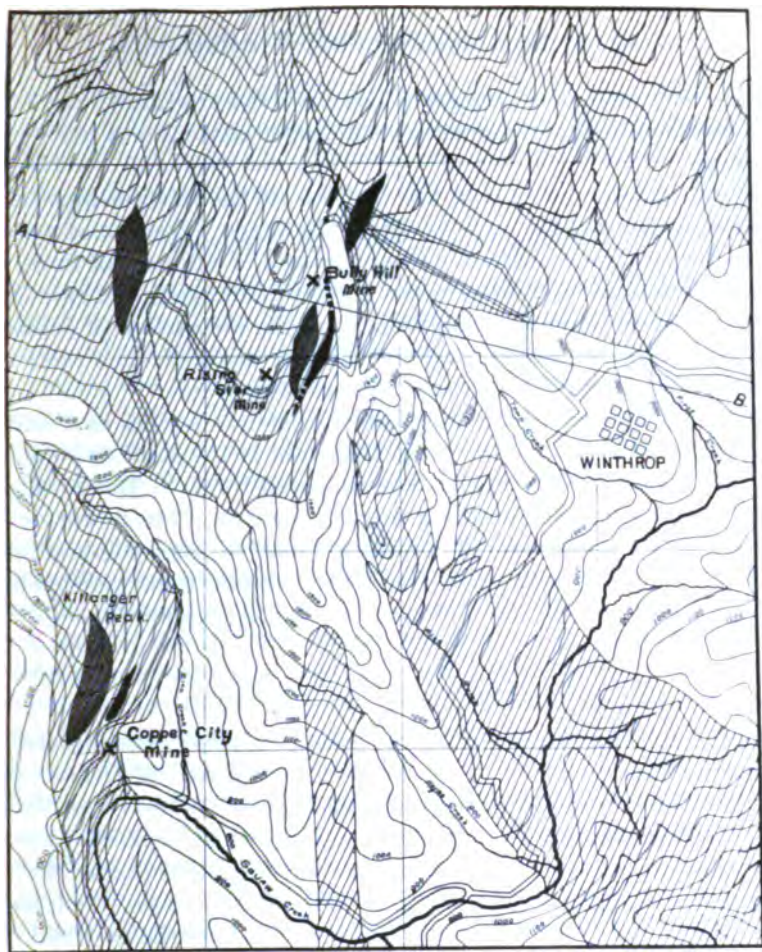


FIG. 1.—MAP OF BULLY HILL MINING DISTRICT, WITH GENERALIZED SECTION ON LINE A-B.

The lower structural section is below sea level and involves the McCloud Limestone.

gangue. By secondary changes which involved alteration, the ores became enriched so that in some cases a copper content of 8 per cent. was produced.

Of considerable interest in this district are the relationships between the shear zones and the various dikes; the shape, extent, and genesis of the ore bodies; the occurrence of large masses of sulphate of lime, which suggests formation by a process not heretofore recognized of great importance. Of great economic significance are the association of copper ores with the alaskite-porphyry, and the interpretation of some facts established in prospecting the extensive masses of gypsum.

The area covered by the map, Fig. 1, extends 2 miles east and west and 3 miles north and south. It is embraced in the *Redding Folio* of the U. S. Geological Survey, which was prepared by J. S. Diller, to whose careful observations the writer is deeply indebted. The recent development of the mines has naturally revealed, however, some points of interest which were not accessible when Mr. Diller's observations were made, and as a result some modification of his views will be supported.

II. LOCATION OF THE DISTRICT

The Bully Hill district is one of several mineral belts situated in a moderately elevated area in the western central part of Shasta county, Cal. This county lies at the extreme northern end of the Great Valley of California and embraces a range of mountains which is chiefly formed by the northward convergence of two important mountain chains, the Sierra Nevada on the east, which has a general north and south trend, and the Coast Range on the west, which has a decided northeast trend. The actual junction consists of short irregular ranges.

The section of the country is roughly in the shape of a flat-lying U with the opening to the south. The Coast Range and the Sierras form the limbs, while the high slope of the Sierras, bearing westward, rapidly merges with the eastern slope of the Coast Range and produces the gentle curve of the U at the north.

Irregular east and west ridges parallel to the curve of the U succeed one another to the north, and present a relatively steep front to the south. The Southern Pacific railway, connecting Sacramento with Portland, passes up the Great Valley and crosses this range by following along the course of the Sacramento river and its tributaries. At a distance of 10 miles north of Redding it passes through the station of Pit, from which the Sacramento Valley & Eastern railway extends to the east 15 miles so as to tap the copper belt at Copper City. The branch finally ends 3 miles farther to the north at the Bully Hill mine, near the town of Winthrop.

The productive area which has attracted attention for the past 13

years and which is now under consideration lies in the immediate vicinity of the town. There are three local mining centers, designated as Bully hill to the north, Copper City to the south, and the Rising Star between these, but somewhat nearer to Bully Hill.

History of the Mining Development

The existence of copper ores in this part of the mineral belt was known in the first decade of the '50's. It was encountered in small quantities in tunnels which were opened primarily for the gold and silver veins which yielded the placer values. In 1853 placer gold was discovered in the vicinity of Bully Hill¹ and in 1862 gold was found in the altered surface rock near the present site of Copper City.² The copper deposits were neglected for the time being, and little of importance happened before 1895.

Oxidized ores from the surface soon failed to yield acceptable returns, and tunneling was employed with the hope of discovering sources which presumably supplied surface values. Tunnel No. 1, on the east slope of Bully Hill about 500 ft. from the top, was driven a short distance. Since the surface somewhat to the west and north had yielded profitable returns in gold and silver, this tunnel was driven with the view of striking the gold-bearing rock in depth. As the working face advanced, the gossan which had yielded the values changed into very base ore. This condition of affairs so discouraged the operators that in a comparatively short time their workings were abandoned, as it was the general belief that such base ores could not be reduced successfully.

About this time Iron Mountain, some 20 miles to the southwest, was located as an iron mine by William Magee and Charles Camden. The surface rocks throughout the entire country were more or less stained by iron oxide; the gossan was thick and usually carried gold values. Practically the same gossan occurred at the abandoned claims on Bully Hill. Since sufficient time had elapsed for the timbering in Tunnel No. 1 of Bully Hill to rot, the property was relocated and later passed into the possession of Alvin Potter, in 1877. The tunnel was reopened and re-timbered. Some ore was taken out, but it exhibited such a base character that active work was discontinued, and subsequently the property passed into the hands of the Extra Mining Co.

It now appeared for the first time that the enterprise was on a firm basis, and in 1877 the first ore-dressing mill in Shasta county was erected near the present site of Copper City by C. M. Peck. The mill was erected on the west bank of Squaw creek and was known as the Northern Light mill.

¹ *Bulletin No. 23, California State Mining Bureau*, p. 32 (1902).

² *Idem*, p. 33.

It is reported that in three years the company extracted nearly \$650,000 from the ores. The rich values soon began to decrease or change in character to such an extent that this mill was abandoned after a comparatively short period of operation. The equipment became the property of Messrs. Potter and Hall, who had purchased some of the adjoining claims, but, like the Extra Mining Co., they were forced to discontinue operations because of the complex nature of the ores.

The entire milling industry was established on the basis of returns from a 250-ton shipment of local ore sent to Swansea in 1863. It is reported that the ore assayed 8 per cent. in copper, and showed a value of \$40 in gold and \$20 in silver to the ton. The copper content was considered of no value.

In 1879 James Salee passed through this section of the country and incidentally visited Iron Mountain. He was a miner of wide experience, and in samples of the gossan which he had collected he found gold and silver values. He became the sole owner of the property at Bully Hill. Years passed and occasionally new finds would be reported, which boomed the Copper City district and gave a new impetus to speculation. Little was done, however, until the latter part of the '90's, when the property was transferred to the Bully Hill Mining & Smelting Co. Such is, in part, some of the early history of the camp.

Topography

The district shown on the map, Fig. 1, is embraced by the Klamath mountains and shows a well-dissected portion of the Klamath plateau. The elements of relief are not many and are easily distinguished. Topographically the most important feature of this region is a ridge of igneous rock formed by the upturned edges of surface flows of andesites and intimately associated tuffs. This complex has been metamorphosed to such an extent that it resists erosion to a greater degree than the limestones to the northwest, on which it rests, and than the shales and tuffs which flank it on the south and east. This ridge is continuous outside the limits of the map for a distance of 30 miles and has approximately a north and south direction.

In general, the drainage of the district is to the southwest until the Sacramento river is reached, after which it is entirely south. To the east of the ridge is Squaw creek, which flows southwesterly and joins Pit river near the southern border of the map. The west slope of the ridge is drained entirely into the McCloud river. This ridge is traversed by a series of narrow and steep gulches separated by steep ridges of a minor order.

Bully Hill may be regarded as an elevation of secondary importance, scarcely more than 2,000 ft. in height. The elevations decrease pro-

gressively toward the southern limits of the map. The topography is intimately related to the general geological structure of the district and results from differential erosion of the various rock formations.

The lower portions of the larger gulches have been partly filled with detritus from the higher slopes, and in many parts of the district these have been worked as placers.

III. STRATIGRAPHY

It is not the purpose of this paper to enter into an elaborate detailed discussion of the stratigraphy of the region, for it has received great care and special attention from J. S. Diller,³ J. P. Smith,⁴ and H. W. Fairbanks.⁵ In order, however, that the geological relations of the eruptive rocks and the ore bodies may be fully comprehended, a brief outline of the separate formations is here introduced. (See Fig. 2.)

The oldest rocks in the Bully Hill district which outcrop on the surface consist of a series of volcanics, everywhere tilted at a high angle decidedly to the southeast, although locally beds may vary so as to be nearly flat.

This series consists of alternate flows and tuffs which together measure roughly 1,500 ft., and has been named by Diller⁶ Dekkas andesite. Above this and apparently conformable are the crumpled massive to thin-bedded shales of the Pit series. Only the lower part of fully 2,000 ft. of the Pit shales is embraced by the eastern boundary of the map.

Description of the Rocks

Triassic Lavas and Tuffs.—Andesite flows and related tuffaceous beds, now greatly metamorphosed, are seen to cover most of the western part of the area under consideration. The shape and areal distribution are shown on the map, Fig. 1. It is a matter of some difficulty, however, to fix the precise divisional planes that separate the earlier from the later flows. This comes about from the fact that one grades into the other. In many instances the flows succeed each other with apparent regularity, and at times were followed by accumulations of tuffaceous materials. The present metamorphosed condition of the tuff beds and the flows makes it difficult in the hand specimen to draw definite divisional planes. From the manner in which this andesite series weathers it is possible to describe two different varieties, but because of limited space the andesites collectively will be described as a single unit.

³ *Redding Folio*, No. 138, U. S. Geological Survey (1906).

⁴ The Metamorphic Series of Shasta County, California, *Journal of Geology*, vol. ii, No. 6, p. 588 (Sept.-Oct., 1894).

⁵ Geology and Mineralogy of Shasta County, *Eleventh Report of the California State Mineralogist*, p. 24 (1892).

⁶ *Redding Folio*, No. 138, U. S. Geological Survey, p. 7 (1906).

The freshest specimens are dark gray, with numerous small glistening phenocrysts of labradorite, showing best on fractured surfaces. The rock exhibits a greenish tinge, due to the presence of chlorite, epidote, and similar secondary minerals derived from pyroxenes (probably augite). On alteration the rock usually becomes lighter colored, and in many places on first sight resembles rhyolite. Occasionally sparsely scattered vesicles which have been filled with calcite occur, and the presence of these gives

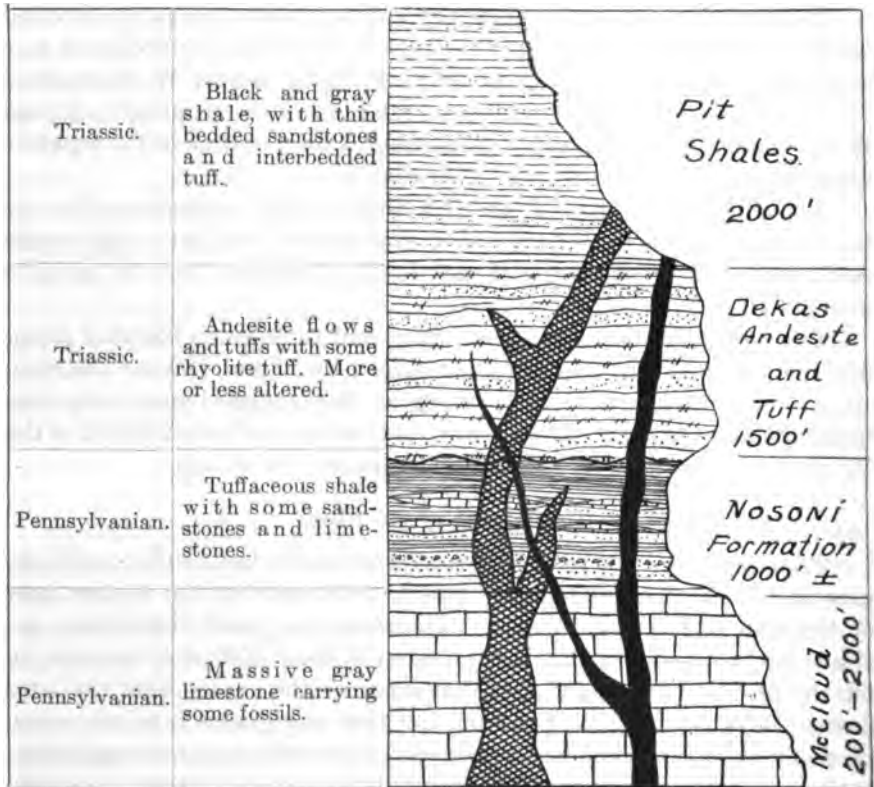


FIG. 2.—GENERALIZED COLUMNAR SECTION IN BULLY HILL DISTRICT, SHOWING THE INTRUSIONS.

to the rock mass a mottled appearance. Where the rock is found thoroughly altered it is characterized by a red stain derived from iron-bearing silicates. The secondary minerals are sericite, quartz, kaolin in large amount, and minor quantities of calcite and iron oxide. The alteration is often attended by leaching by which the rock changes to a nearly white mass, roughly schistose.

In the valleys where this andesitic material has accumulated characteristic red gravelly soil results, which because of the red color makes it

impossible to trace the series where the outcrops are obscured. The massive character of some of the flows is evidenced from the presence of numerous large rounded boulders, which are to be seen in the gulches as placer gravels.

Triassic Sediments.—The Pit Shales.—The youngest formation in the district with which this paper is immediately concerned is an extensive series of shales, interbedded occasionally with various volcanic tuffs. In general these shales are fine-grained, dark gray to black, characteristically thin-bedded, and frequently provided with remains of minute marine organisms.

This terrane is by far the most extensively developed of any formation in the district and covers the entire area of the eastern part of the map. These shales underlie a limestone having an abundant and well-preserved fauna which is known to be Middle or Upper Triassic.¹ Because of this relationship the age of the shales is placed in Middle Triassic.

The average strike is north and south when large areas are considered, but on the map it will be noted that the strike varies. The dip is decidedly to the southeast, in common with the previous series, and in amount it is not far from 28°. Variable dips are encountered in the southeastern part of the map.

Where the shales exist the topography is well rounded, and usually low lands result. This is not because the series is characteristically soft, for there are some members making up the deposit which are hard and resistant; but because a few soft layers or beds exist. These are usually tuffs, and as they are washed away the harder parts, because of insufficient support, break away and the entire formation is thus weakened and the topography is thereby subdued.

The rock types include brownish red to yellowish red shales and tuffs. The shales alter to lighter shades, browns and grays predominating. Because of folding the entire formation is jointed and shattered, and overturned folds are not uncommon.

Areal Geology

The area mapped consists of Triassic rocks, which can be deciphered into several distinct types. Along the southern and eastern border of the map are found sediments, chief of which are shales, sandstones, and interbedded tuffs. The area embraced shows only a small part of a widespread series which extends north and south for many miles, and stretches over a distance of 10 miles or more in width to the south. The western border of the area is rather irregular, a condition produced in part by stream cutting, but largely by complex folding and erosion.

West of the sedimentary portion is an extensive area of igneous rocks

¹ *Professional Paper No. 40, U. S. Geological Survey, p. 16 (1905).*

comprising andesites and andesitic tuffs. These rocks cover the entire west half of the area under consideration. Irregular masses and long strips extend south and east from the main area. The entire area has been sheared so that the rocks are usually of a pronounced and thinly foliated type. Into the sheared country rock have entered dikes, which tend to complicate the structure. Natural outcrops are abundant and form sharp ridges, persistent for long distances. The hilly tract containing the mines embraces this igneous complex and has abundant evidences of mineralization. The ledges of altered andesite and dikes rise many feet above the general profile, and obviously present what physiographers term a "young" topography. The rocks over wide areas are greatly decomposed, and, except where exposed as already described, have weathered to a mantle of soft, reddish brown, chalky débris; and again they have become so thoroughly silicified that their original character is entirely obliterated. The extent and general areal relationships are given on the map, Fig. 1.

Structure

The rock formations, which have a general southeasterly dip, are complicated by folds, faults, shear planes, igneous intrusions, and metamorphism to such an extent that in the immediate vicinity of the mines these secondary features are of more importance, in the solution of the problems later discussed, than the rock types in which they are so conspicuously found.

In order that the significance of these relations may be fully comprehended, and also that the reader may have at the outset a working knowledge of the local features, it becomes necessary particularly to appreciate the character of the various metamorphic processes involved. There is a very intimate relation between all these elements and the origin of the ore deposits. No single feature when taken by itself explains the situation, but when all are taken together, in proper sequence, they are directly responsible for all the facts observed with regard to the ore genesis. For convenience and emphasis these will be discussed separately.

Folds.—The best preserved folds are to be seen in the sedimentary rocks which flank Bully hill on the south and east. In these rocks the compressive forces have produced a great variety of folds, ranging from those in which the flexure is just perceptible to those where overturning is pronounced. The folds are complicated, variable, and at times very obscure. The simplest type, Fig. 3, is found in the south and east part of the area, and the folds become progressively more complicated north and west until at the contact with the igneous rocks they are apparently lost by grading into another structure later to be discussed.

The prominent phase of deformation especially noticed in the vicinity



FIG. 3.—OPEN FOLDING IN THE PIT SHALES.



FIG. 4.—CLOSE FOLDING IN THE PIT SHALES.

of the mines is that which follows from compression. Within this zone the strata have shortened and the greater length of the various beds, previously listed and described, has been taken up by folding. The bending became complex and later reached a condition in which the units yielded easier to the applied stresses by breaking than by further crumpling. As a result, in the western part of the Pit shales, the adjustment is characterized by numerous breaks in the strata. Since the strata of the Pit formation consist of shales, sandstones, and limestones, there is reason to suspect widely differing structures.

The composition and thickness of the various beds determined in a large way the behavior of the series under the applied stresses. The units varied greatly in thickness, and as a rule the thicker portions yielded by breaking rather than by bending. On the other hand, where the strata were thin and the composition favorable, complex folding and contortion resulted. These finally became more pronounced and were later replaced by thrust and dislocation.

Everywhere the Pit shales are folded, and so prominent is this feature that the formation can be detected for great distances. These strata were not originally deposited in this position, but have been subsequently deformed by lateral thrusts which crumpled the units and caused the folds. As might be expected, folds occur of every degree of complexity. Some are broad and open, others are narrow and compressed; in some the strata are but slightly disturbed, in others the beds are actually twisted, contorted and confused in the most extraordinary manner. (See Fig. 4.)

The whole process is not difficult to imagine, and it is furthermore an absolutely necessary step to follow if one wishes to understand the structural relations in the mines as they now exist. Many of the local complexities observed in the working places are easily understood and can be explained by a knowledge of the structures.

It should be stated that in few places only, in the field directly related to the mines, are there good examples of complex folds in the tuffs. This is not because these have in any way escaped the deformation, but chiefly because extreme shearing and metamorphism have obliterated all evidences of such features.

The greater part of the hill in which the mines are located consists of a series of interbedded andesites, and associated tuffs. Although there is a wide range between these products they show a common behavior in the development of shear and foliation. Over the entire region, of which the area mapped is a small part, there is a likeness in the results that argues similarity of causes and materials.

The units varied greatly in thickness from point to point and often the tuffs were mixed in and incorporated with the flows. The fragmental volcanic rocks appear to have been very abundant and may even have

been predominant in this particular locality. As such they consisted mainly of fine dust particles, but there is evidence also that large amounts of ash, as well as some glassy fragments, constituted part of the accumulations.

The massive brittle rocks were originally the flows and these have furnished the angular fragments of the breccias, while the tuffs, because of their porous texture, permitted adjustment to take place between the individual particles without apparent crush. In extreme zones of shear and brecciation, however, all traces of former structures have been obscured, if not completely obliterated. The composition and form of the volcanic rocks determined to some extent their behavior under the applied stresses. Since there is such an abundance of folded structures in the sedimentary formations on top of the igneous rocks, and a short distance to the west in formations stratigraphically lower, it follows that these deformations exist in some form, however badly preserved, in the igneous rocks as well, because the entire series was subjected to the same stresses and behaved as a structural unit. Just how far these deformations extend in depth is a matter purely conjectural, but it is believed that they have affected rocks very early in the geological column.

As noted above, the general structure of the district is comparatively simple, but there are minor features which tend to complicate it. As a result of the degree of folding, beds which were in the beginning far below have been brought near to the surface. These relationships are shown on the structural section taken along the line *A-B*, Fig. 1. Actual measurements at depth could not be made, but the surface relationships are mainly correct. As will be seen, the structural section is made in a line which is parallel to the direction of thrust and consequently the axes of the folds in the slates and the more complex shear zones in the igneous rocks trend northeast and southwest. Furthermore, the axes of the folds pitch, so that the tendency is for the ore bodies to pass into deeper rocks going northward.

Faults.—The structure of the district is affected only in a very subordinate way by faults, but where these do occur they are a source of further complexity. Since the readily distinguishable beds found in the immediate vicinity of the mines show no evidence of extensive faulting, it is safe to infer that no dislocation has taken place since these were laid down. It is possible, however, for faults to have taken place in the earlier rocks and yet not be registered in the sediments within the area mapped, but field study does not reveal any. There are numerous minor slips and dislocations in the rocks, but these are attributed to shearing processes.

Such slips have been encountered in prospecting work, but they are too local to be recognized as being important in the larger structural features, and they are too numerous to be shown on the map. In the

mine workings the older fractures have been rehealed, while the later cracks are still open and furnish circulation channels.

At only two points has faulting taken place on a scale that merits attention, and even here the data are somewhat obscure, so that the actual amount of dislocation is questionable. Further developments may reveal some interesting relationships. The shear zones which stand up as silicified ledges on the hill-top apparently end in the south slope of the hill. It is quite possible, however, that these shear zones are local; but there are several dikes, which will receive attention under "Intrusives," which also outcrop on the south slope of the hill, and these also end rather abruptly. After apparent shifting to the west about 100 ft., they continue in their normal direction southward and finally disappear under the shales. This is very suggestive of a fault when taken in connection with the dikes and the shear zones, but the shales only a short distance to the east show no evidence whatever of any dislocation.

Another possible fault, which is better characterized by being a "crush zone," is seen on the north slope of the hill where it crosses Town creek just northwest of the main tunnel entrance and back of the company houses. Here the rocks are badly brecciated and the zone is apparently vertical and at right angles to the foliation planes of the rock masses on each side. This zone has been partly explored in depth and some ore obtained. Aside from these two instances (and they are rather obscure) no faults of importance were found in the district.

Shear.—A structure which is intimately related to the folds and thrusts is that of shear. It may be regarded as the limiting phase of combined folding and thrusting processes. In this district sheared structures are prominent and are almost wholly restricted to the igneous rocks. While the massive igneous rocks show this structure to some extent, it is best developed in the tuffs, and in some of these it is so persistent that the rock in places may be regarded as typically schistose.

Just as the shales are characterized by being folded rocks, in like manner the igneous members can be considered as sheared rocks. Just where folding ends and shear begins is not always easily determined, since one passes by gradual transitions into the other. In a general way shear is characterized by being a finer structure and represents a greater degree of crush, and involves changes other than those of purely dynamic character. That folds and thrusts preceded shear in the igneous rocks there can be little doubt, but the persistent type structure now seen is shear alone.

The shear has developed mainly at right angles to the direction of pressure and has a general trend corresponding to a north and south plane. In the district under consideration the shear has taken place on a small scale in all the rocks and is widespread, but there were conditions which favored localized shear zones, and as a result Bully hill is char-

acterized by three independent zones which are approximately parallel to each other but separated by intervals of several hundred feet. These zones are nearly vertical and have a north and south direction. They are seen as irregular ledges which project above the general profile of the hill and are shown in Fig. 5. The material constituting the rock of these ledges is mainly silicified andesite tuffs and flows. In this hardened condition it resists the weathering processes and gives rise to rugged, steep slopes. In spite of the rock being hard it splits easily in a plane parallel to the foliation and is often characterized by an abundance of long parallel cracks trending north and south.



FIG. 5.—LOOKING NORTH FROM KILLANGER PEAK AT BULLY HILL.
The picture shows the three shear zones.

The Intrusions

From observation of the succession and character of the intrusives of the district they present in their structural relations one single type—dikes, which are found well exposed on the southeast slope of Bully hill. They may be divided into two distinct varieties, an earlier acidic (alaskite-porphry), and a later one of andesitic characteristics.

Alaskite Dike.—The alaskite dike, Fig. 6, is found in detached masses on the east slope of Bully hill and apparently ends at the Rising Star mine, 0.75 mile farther to the south. The rock is medium even-grained and contains a few small phenocrysts of quartz and feldspar in a fine-grained ground mass of mottled gray color. The freshest specimens

have practically no dark silicates. Most of the outcrops exhibit alteration and intense bleaching, so that the weathered, rough, projecting masses are colored by iron oxide, the colors ranging usually from yellows through reds to pinks.

In the hand specimen the actual dimension of the grains is seldom greater than 5 mm. Much of the rock is fine-grained and may be regarded as felsite-porphyry. Of economic significance are the nearly vertical foliation planes and the cracks along which ore-bearing solutions have deposited ores in notable amounts.

The time of the intrusion is not definitely known, but since the



FIG. 6.—VIEW SHOWING THE RUGGED CHARACTER OF THE ALASKITE-PORPHYRY.

country rock is believed to have accumulated in Middle Triassic time, it follows that the intrusion is as young at least as the late Triassic.

Andesitic Intrusion.—A later intrusive of decidedly andesitic affinities, mostly decomposed to a reddish brown exfoliated mass, is exposed on the south slope of Bully hill and extends in a more or less continuous mass in a northerly direction for a distance of 0.75 mile. Because of the readiness with which this dike rock alters, it is mostly obscured, and at times it is difficult to distinguish it from the country rock through which it passes. Were it not for the exposures in ravines and gulches one would notice little difference between this rock and the normal weathered country rock.

The main body of the dike is nearly vertical, irregular, parallel or nearly so to the alaskite dike, and at several points it is coincident in

course with the direction of the main ore bodies. In the deeper workings of the mines it is known to have a thickness of approximately 300 ft. To the south of the Rising Star mine it pitches under the shales and disappears.

In the hand specimen it is greenish to grayish in color and is usually very fine-grained, although at times it is coarse enough to show distinct phenocrysts. It frequently exhibits amygdaloidal structure. The cavities in all cases are filled with calcite.

In common with the alaskite this dike sends off branches which underground give considerable trouble and annoyance in mining operations. Some of the smaller branches are finely felsitic in texture.

The dike has been changed by shearing and alteration, so that in the mines the dike material exactly resembles sheared masses of ore. With reference to the age of this intrusion, it is the youngest igneous outbreak found in the district mapped, and although a definite age cannot be assigned to it, it is known to intersect the lower members of the Pit shales and therefore must be as young at least as the series, which is considered as Upper Triassic.

IV. PETROGRAPHY OF THE ROCK TYPES

The chief object of the microscopic study of the rock types has been to identify them and to suggest processes directly connected with the genesis of the deposits. Although the metamorphism is complex and the processes of mineralization have persistently overlapped other stages, it is believed that the best results will be obtained by attempting, as far as possible, to treat the various stages as individual and separate phases even though the several processes have been simultaneous.

The specimens of rock have been collected in a systematic study of the Bully Hill district, and represent quite fully the range of types. In the set of rocks which has been selected as typical, microscopic study shows the following: (1) andesites, andesite tuffs, and some rhyolite tuffs among the pyroclastics; (2) alaskite and andesite as the representatives of the intrusives.

Tuffs, of both the andesitic and the rhyolitic varieties, are the dominant types and include 11 specimens of the total 24. Next in importance are the andesitic flows which give rise to the breccias. Then follow the intrusives, which can be grouped into two main types: extremely acid and moderately basic.

The phases of mineralization may be listed under several different heads, but this arrangement does not mean that the processes necessarily followed one another in definite sequence. Aside from dynamic changes, a study of thin sections shows that all of the following processes have been operative in producing the present characters in the rocks and ores.

They are: sulphatization, carbonatization, sulphidation, chloritization, serpentization, and silicification.

Andesite Flows

The andesites range in texture from distinctly porphyritic to finely felsitic and glassy varieties. The characteristic andesite is a close-textured, dense, grayish to greenish rock containing visible phenocrysts of feldspar in a greenish ground mass. The representatives of this class accumulated as thick flows, in some of which crystallization was well advanced before movement ceased.

The felsitic and glassy varieties are without doubt those which were poured out on the surface as thin flows and sheets. In some of these the escaping gases have left the mass porous, but this feature is not always prominent. The microscopic features show the porphyritic varieties to consist of labradorite with some hornblende in a felsitic ground mass. The feldspars are large and contain numerous scattered inclusions, presumably ilmenite. In the finer-grained varieties the feldspar and hornblende wane and in the glassy facies these minerals entirely disappear.

Only fragmentary evidences of biotite remain and in the highly altered types this is often indicated by the arrangement of grains of magnetite.

The transition of the porphyritic types to the finer-grained varieties is gradual but distinct. The alteration of the andesites is a very salient characteristic. Aside from the ordinary weathering to chlorite, kaolin, and epidote, some sericite was noticed, especially where the rocks were badly crushed. Some of the larger phenocrysts of feldspar show internal strain, as seen in the wavy extinction. Where the crush has been extreme the phenocrysts are badly broken and comminuted. The glassy types show only irregular areas traversed by numerous cracks and fissures. For the most part such areas show advanced divitrification, so that in the present form they resemble mottled patches with irregular boundaries. Under the high power of the microscope such areas resolve into an aggregate of quartz and feldspar. In cases where devitrification has not progressed too far characteristic glassy textures are still to be seen.

Tuffs

Only a small number of types belong to this group and each is designated according to the kind of lava fragments it contains. As a whole these rocks do not possess great petrographical interest. In the hand specimen they are not conspicuously fragmental, but if examined with a pocket lens they will be found to contain lighter and darker colored grains imbedded in a gray ground mass. Numerous small specks of magnetite are present. The following types seem to deserve mention:

Andesite Tuff.—The andesite tuff includes all the rocks composed of

volcanic detritus which is clearly andesitic in composition. The texture is therefore of wide range and includes rocks made up of lapilli as well as those consisting of sand and dust. Under the microscope the clastic character of the rock is easily recognized and the mass is seen to be composed of intermingled fragments of feldspars and glass. The andesite tuffs are badly altered or decomposed and this feature renders them very difficult to study. Although the alteration is well advanced and the particles are very fine, yet the microscope shows traces of porosity. Many of the fragments still show evidence of original glassy texture. The tuffs alter to kaolin and sericite, and where the ferro-magnesian minerals have been prominent these have given rise to considerable amounts of chlorite and iron oxide.

Rhyolite Tuff.—In the essential features the rhyolite tuff does not differ markedly from the andesitic variety except in the presence of quartz phenocrysts imbedded in a large amount of dust-like material. This dust may have been in part glassy, but the present metamorphosed condition of the products makes any trustworthy statement of the original condition uncertain. The range in size of fragments is variable. Rarely do the particles exceed 5 mm. in diameter and three-quarters of the entire mass is less than 1 mm. in diameter. The presence of quartz grains makes the identification of the rock comparatively easy. This rock involves glassy fragments as well as mineral grains, all of which are sharp, angular particles, exactly analogous to volcanic detritus. Although the macroscopic evidence indicating that the rock is tuffaceous is strong the microscopic evidence is still stronger and demonstrates completely its volcanic origin. Numerous stringers of partly devitrified glass are to be seen, together with numerous small grains of magnetite. Like the andesite tuffs, these rocks are also porous, and when altered give rise to sericite, kaolin, and some leucoxene. The kaolin occurs as irregular earthy patches and in some slides makes up a large part of the rock mass. The sericite had its origin in the feldspars and usually occurs as fine aggregates.

The tuffs as a whole are mineralized and this phase will be described in detail on a later page.

Eleven specimens out of the 24 are fragmental in character and were originally composed entirely of volcanic detritus. They are the tuffs. The fragments vary in size from 3 mm. down to fine dust. Two specimens of the 11 are best classified as andesite tuff, while the remaining ones are decidedly rhyolitic in general make-up. Nine of the 11 specimens show pyrite in varying amounts from fine sprinklings of dust-like particles, not exceeding 3 per cent. of the mass, to those in which the sulphide runs as high as 20 per cent. or more. One specimen shows blende in minor amounts. Seven show the presence of chlorite and serpentine, while two show notable amounts of carbonate. Seven show the presence of gypsum and all show traces of silicification.

Of the tuffs there is one specimen that deserves special comment since it shows some interesting features not commonly seen in the rest but which are believed to be general throughout the entire class of tuffs. This particular feature is to be noted when the sulphate encroaches upon and entirely replaces the quartz grains, Fig. 7. In the same section pyrite is seen encroaching upon quartz grains and completely replacing them. It appears from these slides that the conditions under which the solutions existed were such that silica was dissolved and a sulphide as well as a

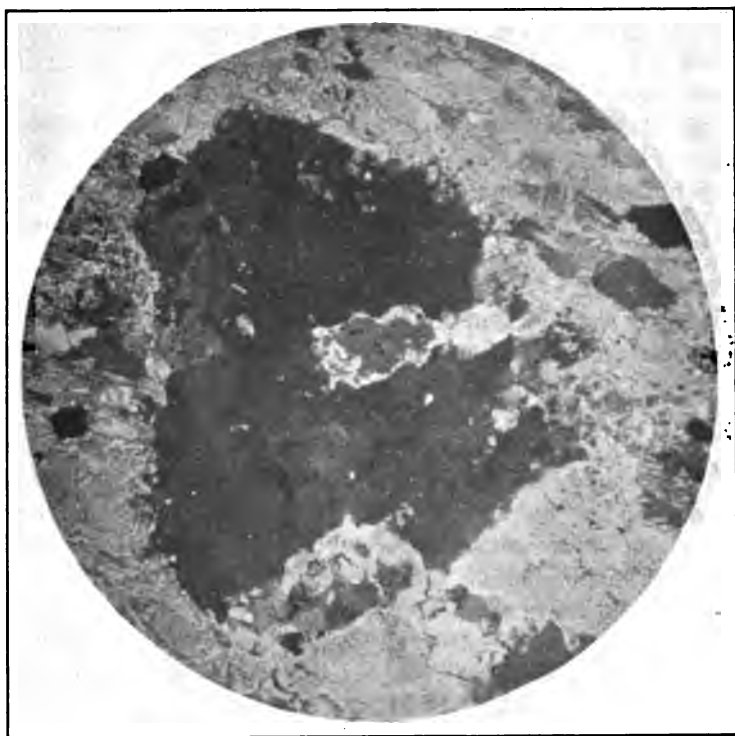


FIG. 7.—DARK AREA IS A QUARTZ GRAIN IN RHYOLITE TUFF.

The quartz is being replaced by gypsum, shown in the upper right-hand area. $\times 50$ diameters.

sulphate was deposited. It is well known⁸ that the solubility of gypsum decreases with increase of temperature above 100°C. , and that silica is dissolved with increase of temperature. It is quite possible that the limits for the solubility of gypsum were closely approached, so that the sulphate already in solution was thrown out and silica taken up. Clarke⁹ states that "Hot waters, charged with sulphuric or hydrochloric acid,

⁸ Seidell: *Solubilities of Inorganic and Organic Substances* (New York, 1911).

⁹ *Bulletin No. 491, U. S. Geological Survey*, p. 459 (1911).

attack nearly all eruptive rocks, dissolve nearly all bases, and leave behind, in many cases, mere skeletons of silica."

Two specimens of the 24 are typical breccias, the fragments of which are angular in character, greenish in color and cemented together with gypsum. These rocks are of such unusual petrographic character that they well merit special description. The fragments, although originally sharply angular, are now conspicuously sheared and at first sight resemble

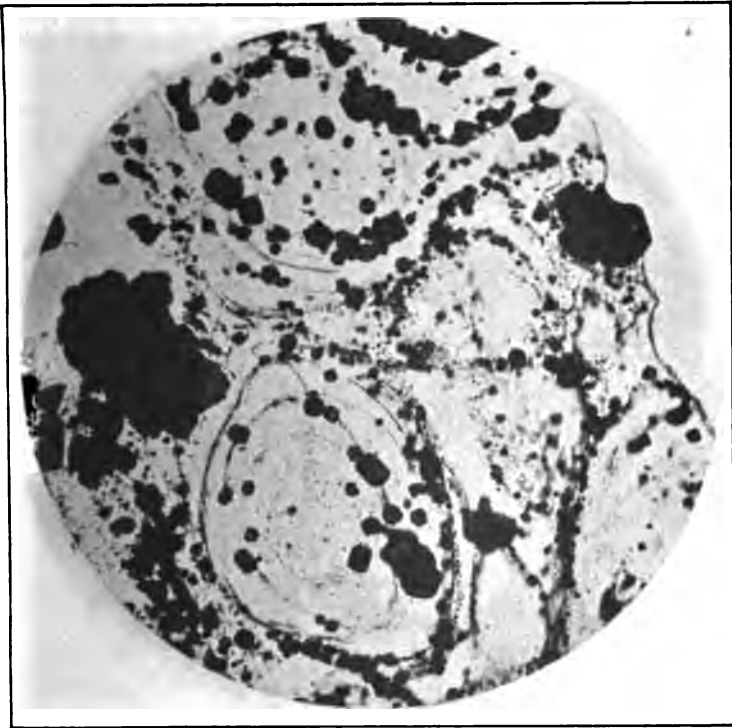


FIG. 8.—THIN SECTION OF A GREENISH FRAGMENT FOUND IN GYPSUM.

The curved lines, accentuated in part by the arrangement of the black sulphide grains, are interpreted to be perlitic cracks of a glassy rock. $\times 50$ diameters. Transmitted light.

pieces of serpentine. They are usually very soft and at times are fissured with carbonate and sulphate of lime.

Scattered through many of the other specimens are greenish areas which closely resemble the fragments of the breccia in hand specimen, but a study of thin sections shows that the fragments of the breccia were originally glassy. In spite of the degree of shearing that is in evidence in most of the surrounding rocks, and also in these specimens as well, many

details of their original texture are preserved with a sharpness scarcely to be looked for in rocks which have had such a history.

It is generally agreed that dynamic action is a powerful agent in completely obliterating all such structures, but in this instance it does not appear to hold true. Glassy rocks are known to be more easily attacked than many others and are subject to either alteration or complete destruction, so that preservation of the glassy breccia without apparent loss of its original earmarks and quick-chill characteristics must be regarded as very

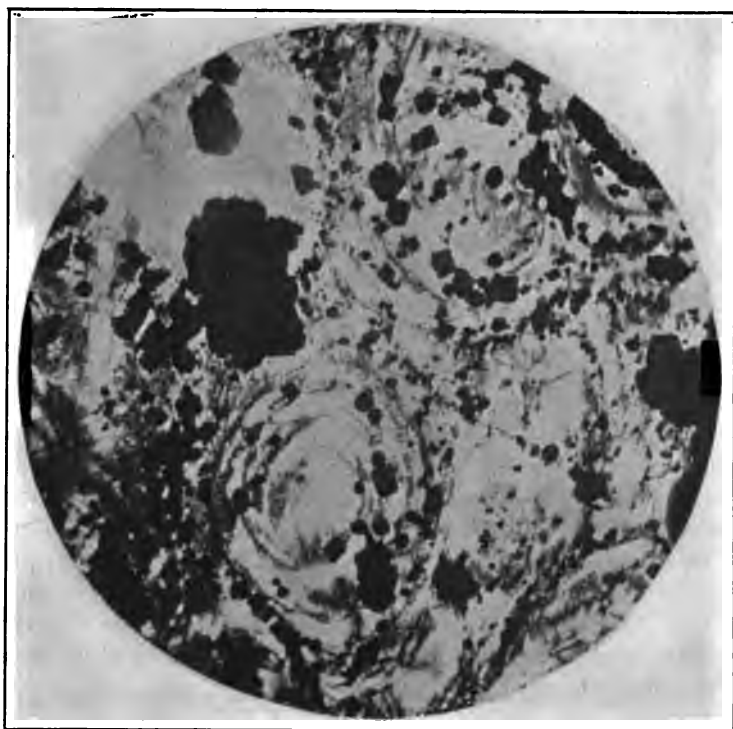


FIG. 9.—SAME SECTION AS FIG. 8, BUT UNDER POLARIZED LIGHT.

interesting, if not exceptional. In the hand specimen the rock presents a uniformly sheared crystalline matrix in which are imbedded greenish fragments varying in size from an inch in diameter downward to microscopic dimensions. Most of the fragments are heavily pyritized and the individual grains of pyrite are conspicuously arranged along curved lines which are exactly analogous to perlitic cracks, Figs. 8 and 9. Many of the fragments show distinct flow lines under the moderate power of the microscope. In the hand specimen they often show how the fragments have been drawn out into "Augen." In some types this arrangement

of the fragments gives to the larger rock masses a distinctly banded appearance.

In thin section the greenish grains are either isotropic or else they show devitrification changes. No chemical analysis of the greenish fragments has been made, but since they are closely related to flow rocks they are provisionally classed as acid glasses. In one thin section the greenish patches show original porphyritic habit. These areas generally represent original glassy rocks and they are certainly being replaced by the gypsum. Stringers and shreds of such material are being encroached upon from all sides, and they remain as cores. Like the breccia, these greenish areas are heavily charged with sulphides, and the conclusion is made that the same mineralizers which introduced the sulphates were influential in introducing the sulphides as well. The sulphate was introduced as a vein filling, and this feature establishes its secondary character. As in the case of the breccia, these rocks were originally flows and are best regarded as acid glasses.

One specimen out of the entire series is classed as a rhyolite flow. It is badly sheared, and under the microscope shows corroded and embayed grains of quartz. Secondary carbonate has replaced some of the ferromagnesian minerals, and this feature gives to the rock a mottled appearance. There are a few patches of divitrified glass which still show pronounced flowage. There is no evidence of introduced sulphate or sulphide. Small amounts of secondary silica are to be seen in microgranular patches.

The remaining specimens are grouped as dikes, and out of the total number of rock types there are eight representatives which can be described under two types.

Under this head are included only those dikes which are intimately related to the ore deposits. There are others in various parts of the area mapped, but they all have a striking similarity in structural relationships. For convenience they will be described in order of age.

Alaskite-Porphyry

This is the most conspicuous dike rock in the district. It is generally light colored, very acid, and is at times mottled. The phenocrysts or the rock consist of quartz and feldspar, the feldspar generally slightly predominating. The ground mass is seen to consist of a microgranular mixture of quartz and feldspar. Some of the larger phenocrysts of feldspar, because of orientation, do not show the usual twinning. The chief accessory minerals are magnetite in small grains, apatite, and rarely zircon.

The quartz phenocrysts are embayed and heavily corroded, as seen in Fig. 10. The feldspars are altered in part to kaolin. There is little or no sericite, and the specimen is notably free from mineralization. The rock

mass has been fractured but has been later recemented by quartz. The alteration products are chlorite and epidote in small amount, derived in all probability from original flakes of mica. The dike varies in thickness and on thin edges it is relatively fine grained, while in the center of the larger masses the texture is rather coarsely grained.

Although in places the rock shows conchoidal fracture it contains no glass. Diller¹⁰ regarded this rock as a surface flow and recorded it as being



FIG. 10.—CORRODED PHENOCRYST IN ALKALI FELDSPAR PORPHYRY.

Light area, quartz; dark area, unaltered ground mass. $\times 50$ diameters. Crossed Nicols.

older than the sedimentary formations apparently resting upon it. From his various published statements regarding these relationships it may be inferred that such a conclusion was not reached without some hesitation. Recent study of the structural relations in depth shows that all such masses can best be regarded as intrusives, and this idea was entertained by H. W. Fairbanks.¹¹

¹⁰ *Redding Folio*, No. 138, U. S. Geological Survey, p. 8 (1906).

¹¹ *Eleventh Report of the California State Mineralogist*, p. 32 (1892).

Andesite Dike

In appearance the andesite dike is a dark gray to greenish fine-grained rock, sometimes showing a tendency to amygdaloidal structure. The microscope proves that the rock consists of phenocrysts of orthoclase imbedded in a fine-grained ground mass of lath-shaped feldspars. The chief accessory minerals are magnetite and rarely rutile. The rock appears more basic than is actually the case. It varies in composition from point to point and shows in its northernmost outcrop the presence of some pyroxenes. Like the alaskite dike, it also sends off branches into the country rock, and these are finely felsitic. Both dike rocks have been sheared and have been replaced in part by sulphides, sulphates, and carbonates. Although the dikes vary from point to point the following analyses made on typical specimens of the freshest material will give an idea of their chemical character.

Analyses of Alaskite-Porphyry and Andesite Dike

	(A)	(B)	(C)
SiO ₂	78.50	81.25	49.85
Al ₂ O ₃	11.50	9.03	17.00
Fe ₂ O ₃	0.11	0.63	4.02
FeO.....	1.82	0.40	5.51
MgO.....	0.46	2.48	7.65
CaO.....	0.50	trace	1.18
Na ₂ O.....	6.04	0.25	4.78
K ₂ O.....	none	1.82	none
H ₂ O at 105°.....	0.30	1.09	2.16
H ₂ O above 105°.....	0.82	2.81	6.65
TiO ₂	0.27	0.08	0.97
P ₂ O ₅	0.03	trace	0.10
S.....	0.13	0.35	0.07
SO ₃	none	none	none
CO ₂	none	none	none
MnO.....	0.03	trace	none
BaO.....	none	0.05	trace
ZrO ₂	none	none	none
Totals.....	100.51	100.24	99.94

(A) and (B), Alaskite-porphyry dike rock near Bully Hill mine, rich in porphyritic quartz. (A) analyzed by George Steiger, (B) by E. T. Allen.

(C), Andesite dike forming the east wall of Bully Hill mine. Analyzed by E. T. Allen. *Bulletin No. 228, U. S. Geological Survey*, p. 210 (1904).

The various specimens of the andesite dike show pronounced shear effects and along such planes there is evidence of introduced carbonates

and sulphides. The carbonates fill irregular cavities, and while the sulphide is often found along the borders of the calcite areas it is not confined to these alone. The cracks and fissures are most heavily mineralized, although in one specimen the sulphide appears to be uniformly scattered throughout the mass. In only one specimen of the andesitic dike rock was sulphate found. One specimen shows introduced copper carbonate.

It is in the andesite dike and its apophyses that the greatest amounts of chlorite and serpentine are found. In all cases these products have been produced by hydrous alteration from former ferro-magnesian pyroxenes as well as amphiboles.

More than half of the specimens contain ores, which are confined to the tuffs. Where the gypsum is found it appears also to favor the fragmental rocks, especially the tuffs. In some of the specimens all original structures are obscured in the various processes of sulphatization, sulphidation, and silicification. In a few there are satisfactory evidences of original minerals and structures that prove the tuffaceous character of the original rock. In the rhyolites the phenocrysts have resisted alteration where all other structures have been destroyed. In such cases the ores are essentially replaced rhyolites and rhyolite tuffs. Some of the specimens show marked crushing and these have been preserved as breccias. The sulphides and the sulphates were deposited in some specimens simultaneously, and in others the sulphides alone are promiscuously distributed through the rocks.

V. DESCRIPTION OF THE MINES

The descriptions are presented according to the geographic position of the three properties in three major groups. The chief producing mines have been divided into the southern, middle, and northern; and comprise the Copper City, the Rising Star, and the Bully Hill, respectively. The writer was permitted personally to visit each of the properties, where ample opportunity was enjoyed for studying both surface and underground geology. Under present conditions such good opportunities are not afforded.

The most southerly of the properties is the Copper City. Although the first property to be extensively worked it is now the smallest. The ore is more difficult to treat than that of the others. The mine is situated about 1,000 ft. west of Zinc creek, and just south of Killanger peak. A tunnel a few feet above the level of Squaw creek has been driven to a distance of 1,000 ft. or more in a northwest direction, and for the greater part of the distance it is in a contact zone between shale on the east and alaskite on the west.

These broad relationships have been modified, however, by extensive fracturing and fissuring, with some shearing, so that while the zone of

mineralization is somewhat irregular, it is roughly northeast in direction and has a nearly vertical dip. The shear zone has been richly mineralized and ore shoots of lenticular shape have resulted. The thickness of these bodies varies from a thin edge on the margins to 14 ft. or more near the middle. The width of the shoots varies from 30 to 150 ft. The central part of the shoot is generally the thickest. The longer axes coincide with the general foliation of the inclosing rocks. Where the walls have been mineralized they have also been mined, but in no instance have they been so productive as to be regarded as important sources of ore.

The principal ore bodies have resulted from the complete replacement of the country rock. The mine is, however, in the early stages of its development, and no very extensive shoot has been mined out. The ore consists of a mixture of pyrite, bornite, chalcopyrite, and an abundance of sphalerite. There are also minor amounts of galena scattered through the masses. In later years the sphalerite has become so abundant as to make the extraction of the copper difficult. The workings have also revealed a badly sheared intrusive dike, containing copper minerals, apparently not original. They are subsequently described.

The next property is about 2 miles to the north of Copper City, and although it is the latest of all to be worked, it is nevertheless of great importance. The mine is called the Rising Star and is situated near the head of Buck gulch, which has its source in the south slope of Bully hill.

The andesites, alaskite-porphry, and andesitic dike are well exposed. So far as known the andesite dike lies wholly to the east of the principal ore body, and, as already stated, is faulted so that detached portions are shifted to the west. The main lodes are lenticular in shape, with their longer axes pitching 60° or more to the north, and having a general strike of N. 10° E. The shoots have been formed by replacement of the sheared rock.

The ores are mixtures of sulphides, chief of which are pyrite, chalcopyrite, and bornite, with small quantities of sphalerite. Of special interest in this mine are masses of gypsum and anhydrite, with minor amounts of barite, the latter being sparingly present in the ores. The workings are extensive and have reached a depth of approximately 1,000 ft. The surface geology presents rocks which consist almost entirely of sheared andesites and tuffs highly stained with iron oxide. The andesite dike, although not conspicuous, is known to exist to the north and east of the main tunnel. At the time of this writing no commercial ore has been found east of the dike.

The northernmost property comprises the Delamar lode of Bully Hill. This mine is the most extensively developed of all. It is situated on the south slope of Town creek, which has its source in the northeast slope of Bully hill and the southeast slope of Town mountain. The workings are entered by means of a tunnel, Fig. 11, 1,400 ft. long, which passes into

the hill in a general southwest direction. The shaft near the end of the tunnel is more than 1,000 ft. deep and connects with a number of drifts and cross-cuts.

The geology is similar to that of the Rising Star mine. The general structure is simple, but the details of the structure and the deformation which produced it are not only complex but in some instances are beyond exact determination. This is due to the complex folding of the igneous members.

The ore bodies are strikingly lenticular in shape and conform perfectly to the foliation of the sheared country rock. The lodes lie much nearer



FIG. 11.—THE MAIN PORTAL OF BULLY HILL MINE, LOOKING SOUTHWEST.
Alaskite-porphyry seen immediately above the right-hand end of building.

the andesite dike than those in the Rising Star mine. They are richer nearer the dike and leaner as they are followed toward the west. From detailed study there is no doubt that the shoots represent completely replaced sheared rock, which may be andesites, tuffs, or alaskite porphyry.

The lenticular bodies range in size from masses a few inches in dimensions to those of hundreds of feet in length. The thickness appears to be controlled, in part at least, by the width of the more completely sheared, and therefore the more easily replaced, country rock.

Gypsum and anhydrite occur here substantially in the same way as in the Rising Star mine, and will receive discussion under the topic, "The Gypsum Masses."

Summary.—It is plain from the preceding statements that the mines are located in a line corresponding closely with the shear zone. The shoots are strikingly lenticular in shape, with their longer axes parallel to the foliation of the inclosing rock masses; their longer axes also pitch steeply to the north, and the deposits in places attain a thickness of 30 ft. or more. Additional descriptions of the ore bodies will be given under "Metalliferous Deposits."

VI. METALLIFEROUS DEPOSITS

The metalliferous deposits of the Bully Hill district, so far as known, are simple and uniform, and constitute three principal tracts intimately related to an igneous intrusive (alaskite-porphyry) locally known as Bully Hill quartzite. These tracts are represented on the map and roughly embrace an area of 1 by 3 miles.

The Bully Hill and Rising Star mines form a group comprising the most important ore bodies of the district, and although ore is known at Copper City, and the mines have been operated at irregular intervals for many years, the composition of the ores has until recently made the mine of small importance. Detailed study of the ore bodies shows disconnected but often overlapping masses varying in size from mere flattened nodules several inches in diameter to large masses hundreds of feet in length and 30 ft. or more in width.

These characteristically lenticular masses, which are roughly parallel to the andesite dike previously mentioned, and which lie between it and the alaskite-porphyry, pitch steeply to the north and are longest in that direction. The crushed rock contiguous to the ore bodies and wholly within the shear zone is generally, but not always, impregnated with sulphides. It follows, therefore, that there exist in the mines theoretically two distinct masses of ore, one having a roughly lenticular shape, the other somewhat irregularly replaced brecciated rock. The latter is an important source of ores, and at times is characterized by more or less complete secondary enrichment. It might be stated that while there are two distinct modes of ore occurrence, there is rarely any distinction between the minerals common to both. Occasionally there are residuary cores of rock in the ore which indicate replaced fragments. Aside from this the only distinction is based on sparsely distributed minerals in the country rock.

As the ore bodies lie wholly within a metamorphosed area of igneous rocks, the individual members of which have been sheared and disturbed, it follows that the shoots themselves may likewise be disturbed. Careful study shows that subsequent to the original deposition of the major ore bodies several later dynamic movements have taken place, each producing fractures which have affected the mineral deposits.

Although the movements have for the most part been of the minor order, the subordinate fracturing has taken place mainly parallel to the foliation of the country rock. It is also believed, upon good evidence in the field, that important shifting has resulted at approximately right angles to the existing shear zone. Because of the number and character of the fractures it is impossible to determine definitely the ages of the different movements.

This condition is therefore favorable to the existence of faulted parts of the main ore body, and applies especially to the north end of the Delamar lode in Bully Hill. The evidence—though obscured by the badly sheared country rock, and therefore of rather unsatisfactory character—shows that in all probability the faulted portion can be looked for farther to the east than the main lode in Bully Hill. The strongest evidence bearing on such interpretation is twofold: first, the isolated mass of alaskite-porphry near the eastern end of Bully Hill dump, which is thought to be shifted from a position which it once had near the main tunnel, eastwardly to its present position; secondly, the brecciated zone and otherwise ground-up material just above the wagon road leading to the Rising Star mine and directly back of the company houses as one goes south. This broken and fractured zone is axially in line with an escarpment produced by an abrupt ending of alaskite-porphry just west of the main portal. Such brecciated zones, within the mineralized area, have received secondary enrichment by copper-bearing solutions.

In a broad way the general distribution of the productive ore zones with reference to the various rock formations has been indicated in a previous part of this paper. In all cases the deposits occur in or in close association with altered igneous rocks, generally alaskite-porphry, which because of fracture and partial alteration exhibit various stages of replacement. The occurrence of the ore in depth is indicated on the surface by a reddish, usually porous, iridescent gossan, and is coextensive with it.

When the ore bodies had been finally completed, and when by dynamic movements they were placed above the level of ground water, oxidation resulted and the subsequent production of the gossan began. It is believed that a very great vertical extent of ore was in this manner affected, and it is quite certain that the solutions which leached the surface rocks migrated downward, carrying with them the salts which they could hold in solution, until they came in contact with the reagents which would cause precipitation. It follows, therefore, that the leaner masses below would receive contributions from above and thus become enriched.

The vertical distribution of the ore bodies at present (1913) is known to be 1,000 ft., and at this depth oxidized minerals exist but as compared with upper levels their amount is waning. The downward limit of the copper ores has not been determined.

The areal distribution is shown on the map, but because of the characteristic weathering of the surface rocks, and the subsequent spreading of the gossan, there is no sharp distinction between the country rock and the mineralized rock. In very general terms it might be stated that the Delamar lode can be traced on the surface for a half mile, and the Anchor lode of the Rising Star mine for a quarter mile. The width of the mineralized zone varies, but in round figures it is not far from 300 to 500 ft.

Character of the Ores

In a number of instances pyrite appears to be the chief mineral, with chalcopyrite as a very common and characteristic associate. More rarely, and chiefly in the zones where oxidation and enrichment have been in progress, we find chalcocite, bornite, covellite, and native copper. The typically oxidized ores if followed down to sufficient depth invariably give way to secondary enriched products, and, when these are not prominent, to the unaltered sulphides. Although some grains of metallic copper are found in the superficially changed rock, the decrease in assay values, going downward in the rocks, is doubtless to be explained by the well-known fact that along open, water-bearing, shear and fracture zones, under the action of surface waters, copper minerals suffer rapid alteration and transportation, and only in the uppermost parts of the sheared zone, especially where reducing agents have had play, do we find grains of metallic copper.

At present the deposits of commercial value are mainly those which are below the gossan and are confined to that part of the zone where enrichment has taken place. Wherever the products of enrichment are present chalcopyrite, chalcocite, covellite, etc., associated with zinc blende are found.

Some shipping ore in the Bully Hill district carries as much as 6 per cent. of copper, but the smelting ores, which furnish the bulk of the output, range from 3 to 5 per cent. of copper, and a few ounces of the precious metals, mostly silver, to the ton. The ores of the various mines, as well as different parts of the same mine, exhibit a considerable range in tenor. In the outcrop, where the gossan is in great abundance, small nuggets of gold have been found. It is from this source chiefly that gold has been derived for the placers.

There are many surface outcrops which still yield gold after the rock is crushed and panned. It follows, therefore, that the gossan carries higher values in gold than the ore extracted at depth.

Mineralogy of the Ores

Metallic Minerals (Metals).—Filaments of native copper occur in greatly altered and much-bleached country rock, detailed study of which

indicates that originally the masses were rhyolites or rhyolite breccias. The surface rocks by early mining methods yielded notable amounts of native copper, but at present such materials are not an important source of the metal. Just how the copper accumulated is not known, but in all probability the presence of organic compounds played an important part in its reduction.

Practically all the gold obtained by hydraulic mining occurs in the native state. Although the particles are uniformly small they are usually visible on close inspection in all the detrital accumulations.

In the oxidized ore the gold occurs in a siliceous, limonitic matrix, which, without doubt, contributed to the placers of local areas. From the intimate relation of the gold with the gossan it is evident that a very close association exists between it and the original sulphur-bearing minerals. In the pyrites, however, the gold is in such a state of fine subdivision and is present in such small quantity that it has not been recognized under the microscope. While most of the gangue runs high in iron oxide, the gold is frequently closely associated with cryptocrystalline quartz. In the mine workings, and particularly in the vicinity of the basic dike, there appears to be a genetic relation and close association with barite and sulphides in which the gold is apportioned evenly through the mass. On the surface this mass alters to limonite, quartz, barite, kaolinite, and in a few places to hematite.

Native silver of delicate filiform and more solid shapes has been reported from the upper levels of the mine workings. It is commonly associated with the gold in the iron-stained capping rock, and occasionally with minute quantities of malachite and azurite. The largest and richest masses are found wholly within the oxidized zone quite near the surface. It decreases with depth and is generally accompanied by an increase in zinc and galena, minerals which seriously interfered with the early amalgamation methods adopted at Copper City. It may be stated that in general the occurrence of silver is less common than native copper.

Microscopic Characters of the Ores.—The material for microscopic examination was collected for the purpose of establishing the sequence of ore deposition. In order to study these problems, a series of selected specimens were polished and examined by reflected light, the general procedure following that of the recent researches of Prof. William Campbell and others.

The chief opaque minerals of interest which enter into the composition of the ores of the Bully Hill mining district are, in order of their importance, pyrite, chalcopyrite, blende, bornite, galena, and covellite, with minor amounts of chalcocite. Not infrequently transparent minerals also are present in the specimens, chief of which are quartz, calcite, and gypsum. These minerals, because of the close resemblance to each other

when observed by this method, are best identified in sliced sections rather than by reflected light.

Pyrite.—Detailed studies show that in the freshest specimens of alaskite-porphyry there are no metallic sulphides which crystallized from fusion as did the other components constituting the rock mass. Pyrite is indeed found disseminated through the alaskite, but it is believed that it was formed at a time after the alaskite had solidified. In this occurrence the mineral usually forms aggregates and grains. Individual crystals of free growth and sufficiently large for recognition of the crystal

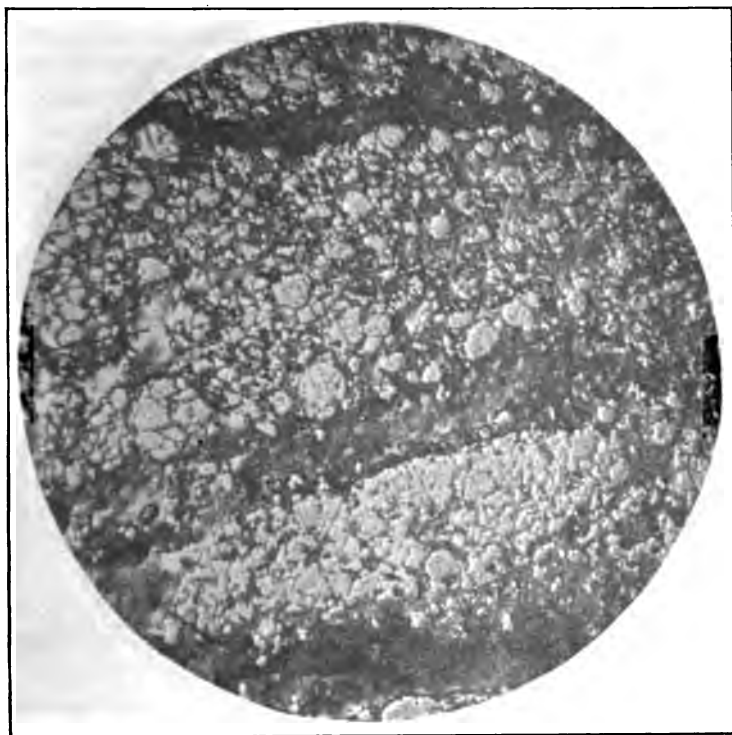


FIG. 12.—LEAN PYRITE ORE WITH VEINS OF CHALCOPYRITE.
Reflected light. $\times 50$ diameters.

habit are comparatively rare. Such faces as are visible indicate that the prevalent form is the pyritohedron, variously modified. When the crystals have been able to grow without mutual interference, which frequently happens in places filled with soft massive gypsum or kaolinite, the usual form assumed is a sharply defined cube, in some instances modified by octohedral and dodecahedral faces. Such forms have been noted particularly in the Delamar lode of Bully Hill. Some brilliant crystals have been found imbedded in a quartzose matrix just to the north of Bagster

shaft. These studies show that pyrite was the first of the ore minerals to crystallize. Whether or not the pyrite is auriferous is not easily determined. That it is not highly so is certain, since tests of the most pyritous matter often show little or no gold, and an abundance of pyrite is generally a sign of poor rather than of rich ore.

Where the pyrite is in masses innumerable branching cracks traverse the specimen in every direction (Fig. 12). As far as could be determined, no other metallic mineral of importance could be seen. This fact does



FIG. 13.—BRECCIATED COUNTRY ROCK.

Filling material chalcopyrite. Reflected light. $\times 50$ diameters.

not fully coincide with the results of chemical investigation, because it is almost impossible to select any sample of lean pyrite that will not give traces of copper. Whether the pyrite contains minute grains of a copper mineral as a mechanical inclusion, or whether the pyrite is a lean chemical compound of copper and iron, could not be determined by this method of reflected light. Aside from the chemical tests the pyrite appears to be pure, and its deposition for convenience has been designated as the pyrite phase.

Chalcopyrite.—The second stage of ore deposition is apparently

characterized by the introduction of chalcopyrite (Fig. 13). This primary mineral closely followed pyrite, although in rare instances, as stated by L. C. Graton,¹² "small grains of chalcopyrite. . . are inclosed in the pyrite individuals." Studies made by the writer point to the conclusion that chalcopyrite has been the last mineral to enter. This mineral completely surrounds the pyrite grains and in some instances enters the minutest fissures of the partly crushed pyrite masses. At times the pyrite and the chalcopyrite are so inextricably mingled that their physical appearances are almost identical, and it becomes difficult if not impossible to distinguish, in the hand specimen, one mineral from the other. In such cases simultaneous deposition may be employed to explain these complex relationships, although from the examination of many specimens the evidence indicates chalcopyrite as being later than the pyrite.

Sphalerite.—Like pyrite and chalcopyrite, sphalerite is one of the primary minerals and is everywhere crystalline. Sphalerite is later than pyrite and is seen to surround particles of this mineral. Unlike the pyrite with which it is so intimately related, it does not form well-bounded crystals even where conditions of free growth appear to have been favorable. The blende is so common throughout some of the ores, especially those near Copper City, that a zinc-extraction plant is now being constructed for its recovery. Near the surface it is easily oxidized, and, aside from a few occurrences, its products appear as sulphates on the walls of the mine workings.

Bornite.—The isometric sulphide of copper (peacock copper ore, Cu_5FeS_4), though moderately abundant as a secondary mineral, is very sparingly found in the primary ore of the district. It is always massive with a recognizable crystalline structure, and is generally met in forms irregularly rounded, closely related to the other sulphides. In no instance is it entirely isolated, but according to microscopic study it is intimately associated with pyrite and chalcopyrite, and in some cases clearly shows close association with sphalerite.

Galena.—Primary sulphide of lead occurs sparingly in the copper ores of the Bully Hill district. It is rarely isolated, but occasionally it is found sparsely disseminated through country rock at the Bagster shaft. It occurs in massive form, both cleavable and granular, rarely crystalline and never crystallized. It is not widespread in any of the mines studied and is found intimately associated with primary chalcopyrite, pyrite, and blende. It has been noted especially in the high-grade sulphide ores of the Delamar lode (Fig. 14) with the other sulphides. It does not occur, so far as known, in the workings of the Copper City or Rising Star mines. Since galena is rarely encountered in depth its alteration products

¹² *Bulletin No. 430, U. S. Geological Survey*, p. 103 (1910).

on the surface were not observed. It is quite probable that the galena as well as the blende is argentiferous, and that would explain the presence of high silver values in the gossan as well as in the regular mine-run of ore. It is plain from a detailed study of the relationships of the minerals that galena favors rich sulphides, especially where blende is in large amount.

Chalcocite.—The cuprous sulphide is not a common mineral in any of the ores of the district. It occurs as dotted masses intimately associated with bornite. Mr. Graton¹³ states that chalcocite and bornite apparently

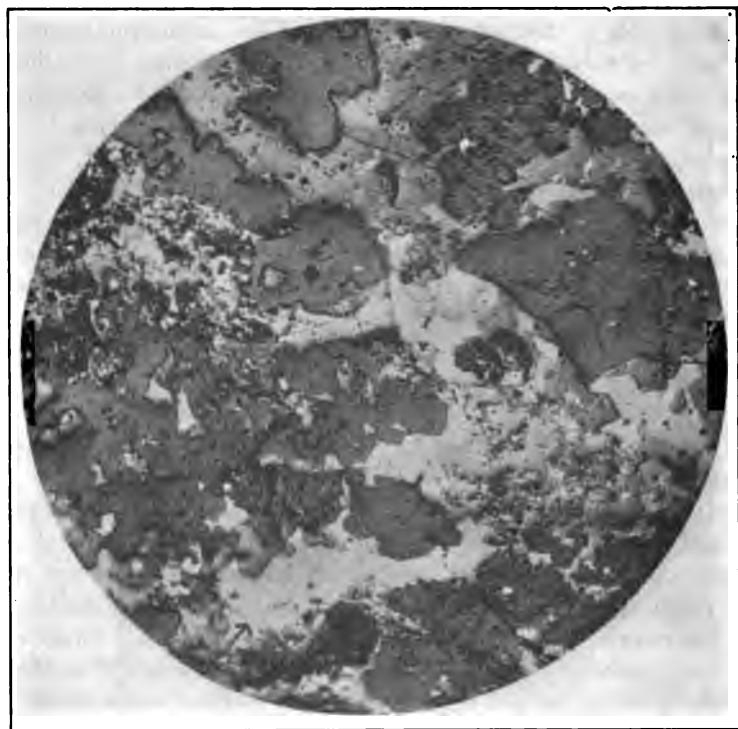


FIG. 14.—RICH COPPER ORE.

White areas, galena; darker, bornite and chalcocite; black, quartz. Reflected light. $\times 50$ diameters.

take the place of chalcocite as an irregular network through and around the other sulphides. Chalcocite was found in small amounts in the deepest workings of the Bully Hill mine and has been regarded by Graton¹⁴ as primary as well as secondary. From recent studies made by the writer, although not rigidly limited, it is generally confined to the upper levels in close association with other enriched sulphides.

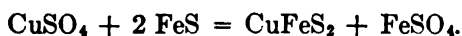
¹³ *Bulletin No. 430, U. S. Geological Survey*, p. 104 (1910).

¹⁴ *Idem*, p. 105.

Secondary Enrichment

The oxidized zone in the Bully Hill district continues, in general, to unusual depths. The lower limit is known to be as low as the 1,000-ft. level. The ore in this zone is considerably enriched, and the enrichment was materially favored by the openness of the mass because of the abundance and relative size of the cracks and fissures, these being possible only in materials which are brittle, such as quartz and pyrite.

The profound modification resulted chiefly through the action of descending waters which in their downward course traversed zones in which small but important amounts of copper-bearing sulphides existed. The following equation illustrates the probable chemical reaction:



As an illustration of the principles of ore deposition, or, rather, ore concentration, this chemical reaction can hardly be overestimated, and since the conditions assume the presence of copper minerals near the surface, this phenomenon is usually related to the second concentration. The first is believed to have been brought about chiefly through the action of ascending hot waters, while the second concentration is almost exclusively related to cool descending waters. It follows from this that if the concentration processes be regarded as cycles the first is far the more important, and as suggested was directly related to the intrusion of the acidic (alaskite) dike. Copper-bearing rock which probably contained less than 1 per cent. of copper will now show from 6 to 8 per cent. in the oxidized zone. Where the replacement has been complete more or less calcite, quartz, and barite are found. It should be stated, however, that while barite has been found in the ores it is not at all important. J. S. Diller¹⁸ regards the barite as a primary constituent of the ores. Calcite and quartz are wholly secondary and occur more or less abundantly at all levels of the various mines.

In most cases observed the mineral relations are fairly definite and leave little room for question. In other relations there is room for more than one inference. The order given is believed to be correct in the main. The disturbing element in most instances is alteration. In no specimen is there any suggestion of a distinctive silver mineral, although the ores yield several ounces to the ton. The presence of other sulphides, notably arsenic and antimony, was not detected. The enriched sulphides taken from the deepest levels of the mines are indicative that the lower limit of descending circulating ground water has not been reached, and therefore that the zone of lean sulphides has not been entered.

One other mineral of great importance and intimately associated with

¹⁸ *Redding Folio*, No. 138, *U. S. Geological Survey*, p. 12 (1906).

the ores, especially of the Bully Hill and Rising Star mines, is the hydrated sulphate of calcium, gypsum. L. C. Graton¹⁶ reports anhydrite as well, but so far, the examination of many slides has not revealed its presence extensively. The explanation advanced for the gypsum will also account for the anhydrite, and this will be given in "The Gypsum Masses."

Genesis of the Deposits

The preceding pages set forth the problems awaiting solution, and only a brief recapitulation is deemed necessary of some of the most significant facts with which an adequate explanation of the ore genesis must harmonize.

The association of the ore deposits with the intrusives is interesting, and a study of the lean ores is one that promises to give most light on their origin. Due consideration must also be given to the mechanical alteration and subsequent changes wrought in the dike materials through which suitable solutions passed, and by which the concentration and enrichment of the ore bodies were made possible.

The fissures produced a weakened zone which not only permitted the solutions to circulate, but determined also the place where the intrusives (dikes) should pass. While it is believed that chemical alteration has facilitated important surface changes, the larger structures of the rock masses in depth are believed to have been caused primarily by deep-seated agents. As far as the andesite flows are concerned, detailed study shows that they were originally almost entirely free from all sulphides.

The limits of the belt which suffered shear in the area mapped are not definitely known, but from data at hand it appears that a strip which measures 1,000 ft. or more in width and several miles in length, at least, has been affected. This zone, which deviates locally, trends practically north and south over long stretches, and it is characterized from point to point not only by variation in width, but also by the degree of mashing and shearing.

A feature of economic significance and one that should receive attention is the fact that the greatest brecciated and comminuted section is not symmetrically located with reference to the side limits of the shear zone; but is decidedly to the eastern border of the belt. Thus in passing across the outcrop of the belt the first few hundred feet encountered closely resemble schists, while toward the west the degree of schistosity becomes less and less until finally the rock masses on the opposite border are practically free from such induced structures.

Another feature which is very conspicuous, especially in Bully hill, shows that locally there are at least three shear zones comprised within the belt. Together they embrace a total width from east to west of approxi-

¹⁶ Bulletin No. 430, U. S. Geological Survey, p. 100 (1910).

mately 1,000 ft. They are seen in Fig. 6, looking northward, as a series of ridges in the profile of the hill. The eastern zone incloses the alaskite dike and contains the Delamar lode of Bully Hill.

The rough, rugged ridges are forms which have resisted erosion more effectively than the surrounding materials. With the exception to be noted, all such ridges are referable to silicified sheared rock, chiefly andesite flows and tuffs. It appears that the materials are mainly tuffaceous, of rather wide range with regard to fineness of grain; and it is believed that such materials, because of their porous character, permitted siliceous waters to circulate more freely than the more massive andesite flows. The solutions came from below and are believed to have transferred silica, which was derived from silicate minerals in the deeper parts of the crushed zone, to its present position. Weathering has also influenced the composition of such materials by dissolving out soluble constituents, so that in some areas the mass is rather porous.

The exception referred to above is found in the disconnected masses of alaskite-porphyry. This material, because of its position and external physical appearance, closely resembles the masses in the shear zones. Close inspection, however, shows the latter to contain small phenocrysts of quartz, while the former contains only secondary quartz. In some instances, especially where shearing has been excessive, and the rock is badly stained by iron oxide, identification can be established only by microscopic study. In the field the alaskite is often mottled with darker patches, and in most instances the rock breaks with conchoidal fracture. These serve as a guide, for such earmarks are never seen in the materials of the shear zone.

Attention will be directed first to relationships, and in this connection they will be described as a unit and will embrace the following elements: (1) what relation exists between the rhyolites and the copper ores; (2) between the alaskite and the copper ores; (3) between the andesite dike and the copper ores; (4) and lastly, between all these and the gypsum masses?

(1). The most important changes in the rhyolites previous to mineralization are those referable to mechanical alterations. The rock masses where brittle were broken and a zone of weakness was formed. After long-continued fracturing the intrusion of alaskite-porphyry followed the weakened zone and was accompanied by magmatic emanations which passed along the borders of the intrusive and were otherwise limited to the zone of mashing. These solutions were hot, especially rich in CO_2 at the beginning, and later they carried ore-bearing and silica compounds. It is believed also that these richly carbonated waters as they passed through the various limy strata dissolved large amounts of lime and transported it to the zone where vigorous shattering had taken place. This seems in accord with the facts, as the veins or fissures are chiefly filled with a mix-

ture of calcite inclosing minor amounts of chalcopyrite and pyrite. The fissured rhyolites were thus cemented by these minerals.

(2). Long before the alaskite had completely solidified stresses again became operative, this time breaking the alaskite-porphry and also disturbing the andesites. Mineralization and impregnation of this rock by metallic sulphides resulted. It is therefore logical to make the statement that this is the first stage in the genesis of the copper ores. Accompanying this change, although not definitely connected with the deposition of the ores, was more or less sericitization, silicification, etc., in the rock masses.

The brecciation forces which acted on the alaskite-porphry finally produced essentially the same shear planes that were observed in the inclosing andesites, so that both rock types behaved practically as a structural unit to all later phenomena. These were important stages in decomposing the constituent minerals, and they were followed by chemical modifications which were later represented by completely altered rock masses and the production of secondary silicates.

(3). Shortly after the production of the foliated structures igneous activity was again characterized by the intrusion of an andesite dike, which also followed the foliation planes, and in places cut across the alaskite-porphry by intruding into the shear planes developed in its mass. Of all the rocks in the Bully Hill district this andesite dike was the last to appear and it closely followed the alaskite-porphry. Outside the area mapped an intrusive rock, in composition more basic than those described, is known. From these relationships it is believed that each fraction from the original magma became progressively more and more basic, and that accompanying the last intrusion magmatic solutions rich in calcite and barite, together with metalliferous compounds, were also given off and reached the sheared zones. These solutions started out hot and in their upward journey they received heat and chemical energy from the dikes which had intruded the rocks and had not cooled entirely. They were thus effective agents and at once attacked the rocks which were most crushed and comminuted. The andesite dike in places was thus encroached upon by the carbonated compounds, and frequently entirely replaced.

Since the andesite dike is partly mineralized it follows that some of the economic minerals were deposited after the intrusion of the alaskite-porphry. It is necessary in treating the genesis of the ores to account for the copper minerals in the alaskite. The most reasonable and logical explanation is that they were transferred by the agency of highly heated solutions. That some of the solutions contained lime is certain, because in the andesite dike numerous cavities filled with calcite exist.

Copper compounds in underground highly heated solutions are doubtless carried in many forms, probably more as acid compounds. Assuming

that pressure and temperature are important factors at depth, a decrease in either of these might furnish conditions under which deposition would take place. Whatever the chemical nature of the solutions that transported the metallic sulphides, it is certain that they were deposited in the sheared alaskite-porphry mass.

The magmatic solutions that followed the andesite dike contributed additional metallic sulphides, chief of which were blende, bornite, and galena. Important amounts of chalcopyrite were also introduced which greatly added to the richness of the ores. It should be stated that in all stages of mineralization the sheared rocks were impregnated indiscriminately. The element of control seems to have been the sheared zone. In several places the andesite dike is partly mineralized, but so far as known the ores appear only as a thin crust or veneer on the dike rock.

Several diamond-drill holes were driven through the andesite dike to ascertain conditions on the opposite side. No ores were found, and so far as known only the hanging-wall side of the dike contains sulphides. In the opinion of the writer the opposite side of the dike rock should be prospected, although it is quite possible that the position of the dike partly influenced the course of the solutions in such a way as to leave the rocks on the other side practically barren. So far, marketable ores have been found only on the west side of the dike.

It is not believed that there were open spaces in the rocks sufficiently extensive to account for the ores as they now appear. A characteristic of many thin sections is compactness rather than porosity, although the porous nature of the tuffs would be adequate to explain ease of circulation in any direction. The interpretation of the available evidence strongly supports the hypothesis of partial to complete replacement, and the facts upon which this view is based may be summarized as follows:

- (1). The lodes preserve structures, especially schistosity, which exist in the country rock.

- (2). Inclosed masses of partly replaced remnants of the original crush-breccia exist as cores.

- (3). In all the ore associations, there is clearly to be seen a gradual transition from rich through lean ore to barren country rock.

The elements involved in the explanation are consistent with the facts and the hypothesis of replacement molecule by molecule of the rock masses by the ores seems to be justified.

In connection with the process of replacement, it is of interest to note how a very acid rock like alaskite, and for that matter the andesites as well, could be partly if not wholly replaced. It has been mentioned that the magmatic waters carried carbon dioxide and that lime was dissolved from strata through which such waters passed. Carbonated waters, as

pointed out by Clarke,¹⁷ are solvents for most of the common minerals, including quartz. It is believed that some of the solutions, thus carbonated, in passing through the disturbed zone attacked the acid as well as the basic rocks and left in most instances only the resistant minerals. Carbonate was in this way introduced, as shown in Fig. 15. It was accompanied in some instances by notable amounts of chalcopyrite.

Simultaneously with the introduction of carbonate, mineral hydration and removal went on, and in some rocks, especially the dike, considerable



FIG. 15.—FELDSPAR IN ANDESITE-PORPHYRY BEING REPLACED BY CALCITE. The felty areas are unaltered ground mass. $\times 50$ diameters. Crossed Nicols.

chlorite was formed. The quartz grains of the alaskite-porphyry were corroded, and in some instances at least were completely removed. The removal of quartz is believed to have taken place through the influence of the alkaline solutions. This phase of the subject will receive detailed discussion under a later heading.

(4). The concordant testimony of a great variety of evidence from a large number of slides suggests several important phases of mineralization

¹⁷ Bulletin No. 491, U. S. Geological Survey, p. 457 (1911).

processes. The study shows that there was a certain definite order or sequence of deposition, although these relations are partly obscured by the deposition of some compounds which began with the earliest stages and continued persistently through the entire process to the last stage. Such minerals as pyrite and quartz are the most important representatives of this class.

The important phases are those genetically related to carbonatization and sulphatization. From a study of thin sections, the former was a process by itself, while the latter included pyritization in addition to sulphatization.

The presence of certain minerals and their various mutual relationships suggest a common source, and also that the source was rich in the elements which form the compounds now found in the rocks. Carbonates, sulphates, and sulphides are seen in nearly every slide in varying amounts.

The most important geological factor which assisted the circulating solutions was undoubtedly the sheared structure of the rock masses. The solvent power of the solutions, under high temperature and pressure, was very great. The ferro-magnesian minerals were the first to be completely altered, and these changed chiefly to chlorite. The feldspars apparently were the next to yield, and alteration has gone on so completely that in most cases very little remains to suggest their former presence. In some of the ore samples grains of quartz, supposed to be the original phenocrysts, still remain, but these are usually badly corroded. Their relations to the ores are shown in Fig. 14.

VII. THE SULPHATE DEPOSITS

In the following descriptions of the various types of sulphates, the rocks will be considered in order of their abundance as they have been found in the mine workings up to the time of the writing of this paper. Whether these relationships as they now exist will continue in depth is a matter on which we have no absolute data, and about which we can only speculate.

The sulphates constitute rocks of considerable importance in the mines of this district. Their existence on the surface with the exception of barite is unknown, and their extent in the working places, although conspicuous, is not usually well defined. The occurrence of sulphates underground is not limited to the upper oxidized zone, but these compounds are known to extend as low as the 1,000-ft. level (the lowest point reached in a shaft in 1912). Although, as previously stated, there are indefinite areal and vertical limits to the occurrence of the various sulphates, still there are fragmentary relationships existing between these compounds and the rocks which serve as a working basis for interpretation. The principal sulphates are gypsum, anhydrite, and barite.

Gypsum

The monoclinic hydrous calcium sulphate ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) is first noticed in the mine workings near the 300-ft. level and from this point it continues downward to the lowest levels of the mine. It is usually of a light gray color, massive to banded, and rarely found in crystals. Its banded appearance is not due to any variation in its composition but is produced by inclusions of other rocks, the fragments of which have been arranged by shearing processes into roughly parallel positions.

At some points it is found in larger masses in a comparatively pure state, but the greater amount in the drifts and tunnels is streaked and locally contains pyrite. The larger masses are soft, usually white and everywhere crystalline. At times the pure fragments are translucent, and it is possible to secure masses several feet in dimensions. Where the rock is in such large masses it is very difficult to mine because of its soft character and its resistance to the action of explosives. For this reason, and also because of the expense of drifting through it, the limits of such masses are not known. Drifts in such bodies are characterized by being noticeably dry.

It is of interest to note that the gypsum as a whole is found limited to the shear zone in depth, and thus far has not been reported from any point on the surface. It is found only in the richest mines, intimately associated with the sheared rocks. In a general way it is seen in the hand specimen to surround masses and fragments of many of the rocks which enter into the structure of the hill.

Anhydrite

The anhydrous calcium sulphate, anhydrite (CaSO_4), is found in the rocks in very close association with gypsum. Like gypsum, it has never been found on the surface. In the fresh state it is marble-like in texture and varies in color from a dull white to various shades of light blue. It is never translucent, and is easily distinguished from gypsum in being harder and in having a pseudo-cubic cleavage in which the planes are perpendicular to each other, but of a somewhat differing degree of perfection. It is less abundant than gypsum and optically differs from it in having moderate relief and high double refraction. The rectangular cleavage is also marked. In thin section it is seen to have practically the same relationships as the gypsum.

Barite

Barite, the orthorhombic sulphate of barium, BaSO_4 , occurs only sparingly in the mines of the district. It is a heavy light-colored mineral

having vitreous luster. This mineral is the only sulphate found on the surface and is usually detected by its glistening crystal faces and the relatively great weight. According to Diller¹⁸ the barium had its source in the feldspars of the alaskite-porphry. After a number of careful tests the writer was unable to detect any barium in the feldspars of this dike rock. It is believed that the barium which furnished the barite had its origin in the same source which supplied the sulphides. Since this mineral is so sparingly present it will not receive further discussion.

Origin of the Deposits, with Special Reference to Gypsum

Before proceeding to a discussion of this subject a summary of the relationships of the gypsum is given. An effort has been made to bring together all the data bearing directly on the problem and also to condense, as far as possible, the descriptions of numerous slides examined. The statements represent facts gathered from the field as well as from detailed microscopic study. A few of the most important relationships are given below:

Field occurrences of gypsum:

1. It is found only in the greatest shear zones.
2. It is never found on the surface in the vicinity of the mines.
3. It begins on the 300-ft. level of the mine and extends to the lowest (1,000-ft.) level.
4. It does not occur outside the zone affected by shear.

Microscopic relations:

1. It replaces quartz grains and glass fragments.
2. It occurs as fissure fillings.
3. It is an alteration product after anhydrite.
4. It completely surrounds rock fragments.
5. It is intimately associated with the sulphides.

In order to explain the conditions given and to account for the origin of the gypsum in this deposit, it will be well first to outline the different theories advanced for the accumulation of gypsum the world over. These are: First, deposition from sea water. Second, deposition through volcanic agencies. Third, deposition by thermal springs. Fourth, deposition through the action of sulphuric acid, derived from pyrites, upon the carbonate of lime. Fifth, Hunt's¹⁹ chemical theory of gypsum formation. This theory is somewhat complex, but Hunt believed it applied to a large part of the gypsum of marine and fresh-water origin. This theory does not apply in this case.

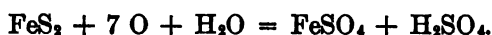
Applying these criteria to the deposit in this district we find that the

¹⁸ *Redding Folio*, No. 138, U. S. Geological Survey, p. 12 (1906).

¹⁹ *Quarterly Journal of the Geological Society*, vol. xvi, p. 154 (1860); *Chemical and Geological Essays*, pp. 80 to 92 (1874).

mode of formation as set forth by the first and fifth theories is not applicable. The second and fourth only demand careful consideration, and for convenience of discussion will be taken up in the reverse order.

Deposition through the Action of Pyrites upon Carbonate of Lime.—This method is perfectly possible and has taken place without doubt in an extensive way in nature, but there are certain initial conditions which do not appear in this region. First of all there must be deposits of limestone sufficiently large to form the gypsum deposit as it now appears. That sulphides oxidize to sulphates is well known. If we start with pyrite the final oxidation products are indicated by the following chemical equation:



It is seen that one molecule of pyrite will yield one each of FeSO_4 and H_2SO_4 . To be on the safe side, it is assumed that both FeSO_4 and H_2SO_4 operate to produce sulphate of lime, although it is very doubtful if the ferrous sulphate acts in this manner. The molecular weight of gypsum is 172 while that of pyrite is 120. If these be converted into molecular volumes it is found that for 74.8 volumes of gypsum we require 24 volumes of pyrite, or that for every 100 volumes of gypsum there must be 32 volumes of pyrite, on the basis that H_2SO_4 only goes to make up the sulphate. Under these conditions, and also assuming that the gypsum in territory not yet explored is as thick as that already found, a uniform bed of pyrite approximately 224 ft. thick would be required. If, however, both FeSO_4 and H_2SO_4 go to form the sulphate, then one-half of this thickness would suffice. There is no evidence that any such deposit of pyrite ever existed in the district.

By the same method of reasoning it is found that to account for the calcium in the gypsum a bed of carbonate approximately 350 ft. thick would be required. There is no evidence that any such bed of carbonate ever existed in the mine workings. On the other hand, there is distinct proof that elastic volcanic rocks, or their remnants, are the dominant rocks of the district. The failure of this theory to explain the deposits makes it evident that this method of origin could not have been the one to which this deposit owes its existence.

Deposition from Thermal Springs, and Through Volcanic Agencies.—These two theories have been grouped as one, since their effects from a geological point of view are very similar. It is well known that emanations from deep-seated cooling igneous magmas are numerous, and, as shown in an important paper by Lincoln,²⁰ consist of acids, gases, and sublimates.

By referring to the structural section, Fig. 1, it will be seen that a massive limestone (the McCloud) has been involved in the folded and otherwise compressed strata. Since this limy member was in the crush

²⁰ *Economic Geology*, vol. ii, No. 3, p. 258 (Apr.-May, 1907).

zone through which the emissions of the igneous magma passed, it is perfectly reasonable that the rock would suffer more or less solution by the acid liquid solutions. These may have been in part water containing CO_2 , SO_2 , SO_3 , or SO_4 . Any of these alone would dissolve the lime carbonate and transport large amounts to higher points. Whether the lime was carried as carbonate or sulphate or as a mixture of the two is a matter about which we can only speculate. It is possible that certain solutions were chiefly carbonate while others were sulphate in general composition. That both solutions existed is shown by the presence of carbonate as well as sulphate in the rocks, but since sulphate is in largest amount it follows that solutions of this character were dominant.

Whether the sulphate was deposited as anhydrite or as gypsum is not certain, although Gratton²¹ from his studies concludes that anhydrite is primary and that gypsum is a secondary product derived from anhydrite. There is room for further study on this point because of the well-known fact that gypsum may be transformed into anhydrite,²² or that the reverse reaction, anhydrite into gypsum, may readily take place. Furthermore, it is known that anhydrite thus formed may be reconverted into gypsum.²³

The writer is fully aware, however, that within the limits of experiment the solubility of sulphate increases up to about 38° C. and then decreases for additional increments of temperature. This is somewhat against the theory of transportation of sulphate, but there are so many variable factors which tend to offset this decrease in solubility that we are driven to the conclusion that these sulphate deposits have accumulated by the transportation of lime by magmatic solutions from deep-seated sources.

Considering the origin of the gypsum deposit as well as that of the metallic minerals so closely associated with it, this theory seems to accord most satisfactorily with all the fundamental relations and facts brought out by detailed study.

VIII. SUMMARY

From the previous descriptions and discussions, and also from a detailed study of all available data bearing directly upon the deposits of this character, the following general conclusions seem to be warranted:

1. The structure is conspicuously closely crumpled, and where slightly overturned the folds are accompanied by breaks which result in a tendency to develop weak crush and shear zones along the chief planes of movement.

²¹ Bulletin No. 430, U. S. Geological Survey, p. 100 (1910).

²² American Chemical Journal, vol. xi, p. 31 (1889).

²³ F. Hammerschmidt: *Mineralogische und Petrographische Mittheilungen*, vol. v, p. 272 (1882-83).

2. The copper ores of the Bully Hill district were originally deposited from magmatic solutions in which the metals were transported as soluble sulphides and were deposited as such.
3. From the character of the metallic sulphides, the associated minerals, and the structural relationships, it appears that replacement has been the dominant process in these deposits.
4. The accumulation and concentration of the ores as they are now found involves secondary enrichment, changes in which precipitation by mingling solutions and reactions on wall rock are of greatest importance.
5. The mineralization processes have apparently taken place under conditions which were entirely independent of rock mass control, as tuffs, flows, and dikes, differing widely in physical and chemical make up, are indiscriminately replaced.
6. The lime as calcite, and the sulphate either as anhydrite or gypsum, had an origin in deep-seated sources, and both these minerals were genetically related to the sulphidation process which has given rise to the ores.

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TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS
[SUBJECT TO REVISION.]

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the New York meeting, February, 1914, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Apr. 1, 1914. Any discussion offered thereafter should preferably be in the form of a new paper.

**The Mill and Metallurgical Practice of the Nipissing Mining Co., Ltd.,
Cobalt, Ont., Canada**

BY JAMES JOHNSTON, COBALT, ONT., CANADA

(New York Meeting, February, 1914)

Synopsis.—A description of the working of the mills of this company and the metallurgical practice in vogue, by which a remarkably complex silver ore, averaging 54 oz. of silver per ton (run-of-mine ore), is treated to give a 95.66 per cent. extraction.

The main features of the processes are:

The cyanide amalgamation of the high-grade ore.

The cyanide treatment of the low-grade ore, after extremely fine grinding and close classification, in a caustic soda solution.

The use of a wet desulphurizing process to break up refractory silver minerals.

The substitution of aluminum dust for zinc dust as a precipitant.

The recovery and shipment of over 13,000,000 oz. of silver in bullion at 997 to 999 fine since this metallurgy was inaugurated, about 2.5 years ago.

On the completion and successful operation of the mill to treat their high-grade ore,¹ the Nipissing Mining Co., under the general management of R. B. Watson, started a series of investigations of the possible treatment of the low-grade ore by the cyanide process, so that they would be in a position to market only silver bullion. These tests were run in July, 1911, on a large scale, by G. H. Clevenger, on an average mixture of Nipissing ore. The results obtained by a partial amalgamation followed by cyanide treatment gave an extraction varying from 90 to 93 per cent. and were sufficiently encouraging to warrant Charles Butters, the company's Consulting Metallurgist, in recommending that the new low-grade ore mill under contemplation should be a cyanide mill, instead of a concentrator. The cost of such a mill, capable of treating 200 tons per day, to obtain a 90 per cent. extraction at a working cost of \$3 per ton of ore treated, was estimated at \$250,000.

In coming to a decision as to which type of mill should be erected, the concentrator, with the subsequent shipping of concentrates to a smeltery,

¹ R. B. Watson: Nipissing High-grade Ore Mill, Cobalt, *Engineering and Mining Journal*, vol. xciv, No. 23, p. 1077 (Dec. 7, 1912). See Fig. 4 of this paper.

was compared with what could be done in a cyanide mill shipping silver bullion 999 fine.

Comparison of Mills Treating 200 Tons Per Day

Commercial assay of ore.....	30.99 oz.		
Correction on pulp.....	1.10 oz.		
Corrected assay.....	32.09 oz.		
Concentration Mill to give an 80 per cent. extraction. Approximate cost, \$160,000		Cyanide Mill to give a 90 per cent. extraction. Approximate cost, \$250,000	
80 per cent. $\times$ 32.09 oz. =		90 per cent. $\times$ 32.09 oz. =	
25.67 oz. at 52 c. =	\$13.35	28.88 at 52 c. plus $\frac{1}{10}$ c. increase price in marketing =	\$15.16
Working costs =	\$1.25	Working costs =	\$3.00
Marketing concentrates, 10 per cent.	1.33	Express on bullion, \$3.50 per cwt. = 23 c. per oz. on 28.88 oz. =	0.07 3.07
Difference between corrected and commercial assay on concentrates = 2 per cent.	0.27 2.85		
Profit per ton	\$10.50	Profit per ton.....	\$12.09
Profit per ton from cyanide mill.....			\$12.09
Profit per ton from concentration mill.....			10.50
Profit in favor of cyanide mill, per ton of ore treated.....			\$1.59

Thus it will be seen that a cyanide mill after having treated 56,600 tons (283 days' run) would have reimbursed the company for the extra \$90,000 required for its construction, providing it were possible to obtain these results.

The actual results which are now being obtained in the cyanide mill are as follows:

Cost of construction.....	\$254,839.52
Extraction on a 26-oz. ore, per cent.....	92 to 93
Working costs, per ton, less than.....	\$3.00
Tonnage treated per day.....	244

The above figures prove conclusively that the results obtained in the preliminary experiments have been more than borne out in actual practice, thus fully justifying the adoption of this type of treatment.

The cyanide mill has an additional advantage over the concentrator, in that it is able to get an extraction of over 90 per cent. on the arsenic-antimony-silver combinations and on decomposed silver minerals found in some veins, on which concentrators can only make a poor saving.

While the construction of the mill was in progress further experimental work was being proceeded with in the expectation of simplifying and bettering the process as it was then known, and to more fully appreciate and overcome the difficulties that others had experienced in their

unsuccessful attempts to make the Cobalt ores amenable to an all-cyanide treatment. Some of these results have been ably recorded by J. J.

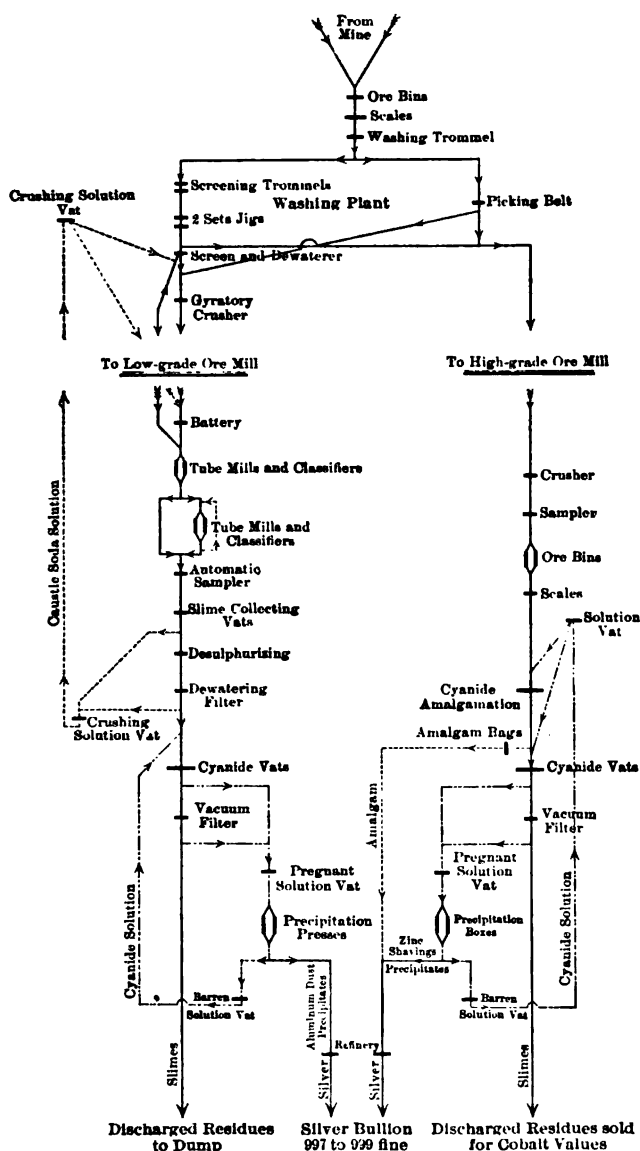


FIG. 1.—FLOW SHEET OF NIPISSING MINING CO.'S MILLS.

Denny.² In regard to the difficulties experienced elsewhere by the fouling of the cyanide solutions where zinc dust was used as a means of pre-

² *Mining and Scientific Press*, vol. cvii, No. 13, p. 484 (Sept. 27, 1913).

gained from these tests resulted in modifications of the plans and flow sheet before the erection was completed, so as to introduce into the treatment the aluminum dust precipitation and the desulphurizing process.

Briefly, the mill practice is as follows:

Crushing the ore to 3 in. in gyratory crushers before sending it to washing plant.

Hand picking and jigging of the high-grade ore in the washing plant, which is then sent to high-grade ore mill.

Discards from washing plant, known as low-grade ore, crushed to 1.5-in. mesh and sent to battery.

Crushing in battery and tube mills in a caustic soda solution to all slimes.

Collecting slimes and desulphurizing in tube mill and vat.

Dewatering slimes and transferring to vats for cyanide treatment.

Filtering slimes and discharging to waste dump.

Cyanide solution from slime treatment vats and filters going to aluminum dust precipitation.

Aluminum dust precipitate taken to refinery, melted, and refined to silver bullion at 997 to 999 fine.

The flow sheet of the process is shown in Fig. 1, and the low-grade ore mill is shown in plan and section in Fig. 2.

The mill site is on practically the highest point of Nipissing hill and is so located that easy tram-line communication can be made between any point on the company's property and the mill. Ample dump capacity for residues is provided below the mill.

Excavations

Excavation was started in November, 1911, and the following data give the cost for soil and rock work. The figures given are fair averages.

Soil Work on Tank-Floor Level, 2,404 Cu. yd.

Labor.....	\$1,369.00
Sundry supplies.....	59.76
Teaming.....	6.03
Blacksmith's shop.....	17.60

Total..... \$1,452.39 = \$0.604 per cu. yd.

Rock Work on Same Floor, 3,144 Cu. yd.

Labor.....	\$5,539.00
Sundry supplies.....	123.52
Explosives.....	279.41
Blacksmith's shop.....	102.75
Air: Drills.....	1,196.32
Hauling rock to dump.....	1,503.68
Lumber.....	25.50

Total..... \$8,770.18 = \$2.79 per cu. yd.

Soil work on other grades cost \$0.41 per cubic yard, and rock work \$1.48 per cubic yard.

Foundations

The walls for buildings and machinery foundations are of concrete. The crushing and mixing plant was located on a level above the uppermost floor and from there the concrete was transferred by chutes and cars into the various foundation forms, the necessary machinery being driven by compressed air. A mixture of 1 of cement, 3 of sand, and 5 of stone, together with the addition of all the large stone the concrete could take as it lay in place in the forms, was used generally throughout the foundations, with the exception of battery, tube mill, and other machinery foundations which are subject to much vibration; for these, the upper 1 or 2 ft. of the foundation was strengthened by the addition of more cement. The following are representative costs:

Battery Foundation and Walls for the Building and Ore Bins

Battery block = 846 cu. yd. concrete

Building and walls = 349 cu. yd. concrete

Total..... 1,195 cu. yd., used 945 bbl. cement

Labor.....	\$2,669.48
Supplies.....	3,735.33
Lumber.....	246.57
Carpenter shop labor.....	790.86
Machine shop labor.....	87.78
Teaming.....	139.34
Fuel.....	12.85
Air for operating machinery.....	400.00

Total..... \$8,082.21 = \$6.76 per cu. yd.

Retaining Walls and Sundry Small Walls and Foundations on Tank-Floor Level

434 cu. yd., used 485 bbl. cement

Labor.....	\$1,645.57
Supplies.....	2,152.52
Lumber.....	337.76
Carpenter shop labor.....	1,180.05
Machine shop labor.....	26.09
Teaming.....	26.33
Fuel.....	12.85
Air for operating machinery.....	300.00

Total..... \$5,681.17 = \$13.09 per cu. yd.

Cement was shipped to the mill in bags, four to a barrel, the total consumption being 3,355 bbl. at an average cost of \$2.06 per barrel.

The various forms for concrete foundations, etc., around the mill made use of 26,339 ft. B.M. of 1-in. boarding and 20,771 ft. B.M. of



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FIG. 3.—LOW-GRADE ORE MILL OF NIPISSING MINING CO., LTD.

other sizes of lumber, part of which when taken down was made use of for other purposes.

The Mill Building

The mill building is constructed of wood framing covered with 1-in. boarding, building paper, and corrugated iron, so as to make a warm



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FIG. 4.—HIGH-GRADE ORE MILL OF NIPISSING MINING CO., LTD.

building for winter service. There was used in its construction 398,601 ft. B.M. of lumber, of which 148,250 ft. B.M. was 1-in. boarding. The

total lumber used in the whole mill was 1,199,206 ft. B.M., at a value of \$23,731.33. Fig. 3 is a photographic view of the low-grade ore mill. The high-grade ore mill is shown in Fig. 4.

The following statements cover the complete cost of the construction of the mill. These accounts were closed about three months after the mill went into operation, so that all the adjustments made necessary after the starting of a mill in which some new departures in metallurgy are being exploited are included in these total costs.

The original estimated cost of this section of the mill as enumerated in the following list of departments was made in October, 1911, and totaled \$250,000.

*Cost of Construction of the Low-Grade Ore Mill (Crushed
and Cyanide Section)*

Departments	Cost to Jan. 31, 1913
Store and office buildings.....	\$725. 65
Proportion office and supervision during construction.....	6,652. 97
Excavations.....	29,728. 30
Foundations.....	20,159. 39
Buildings over mill.....	24,618. 99
Battery equipment.....	24,241. 42
Battery equipment, proportion electrical equipment.....	5,267. 38
Tube mills and classifiers.....	23,223. 80
Tube mill's and classifiers, proportion electrical equipment.....	12,091. 02
Slime treatment and storages.....	31,519. 84
Slime treatment and storages, proportion electrical equipment.....	4,477. 26
Cyanide filter plant.....	14,154. 92
Cyanide filter plant, proportion electrical equipment.....	3,040. 71
Piping, pumps, etc.....	12,886. 19
Precipitation.....	9,989. 23
Precipitation, proportion electrical equipment.....	239. 42
Heating plant.....	12,333. 70
Water service.....	5,288. 57
Water service, proportion electrical equipment.....	1,028. 13
	\$241,666. 89
To this cost was added later the installation of the intermediate filtering and desulphurizing equipment, not included in original estimate....	13,172. 63
Total cost of mill.....	\$254,839. 52

Other construction mill work undertaken at the same time and which would have been common to either a cyanide mill or a concentrator is as follows:

Tram Lines, Washing Plant, Etc., Section

Departments	Cost to Jan. 31, 1913
Crushing, sorting, and jigging.....	\$25,836.64
Crushing, sorting, and jigging, proportion electrical equipment.....	2,274.55
Meyer crushing section.....	5,945.98
Tram lines, aerial.....	18,299.05
Tram lines, Kendall.....	6,499.61
Fixing roads.....	4,386.02
Workshops.....	4,813.14
Proportion office and supervision during construction.....	1,756.26
Total cost.....	\$69,811.25

All the ore from the various workings is delivered into the washing plant ore bins after it has been crushed to 3 in. in gyratory crushers. The ore from the northwest side of Cobalt lake is brought over in a Bleichert aerial tram line 3,560 ft. long, with a rise in elevation between the loading and unloading stations of 172 ft., the longest span being 1,080 ft., the distance across the lake. The tram line runs at 500 ft. per minute and delivers 110 six cu. ft. buckets, equal to about 35 tons, per hour, requiring 10 h.p. to operate it.

The ore from the workings on the mill side of the property is delivered by surface tram lines.

Washing Plant

There are four ore bins, each of 80 tons capacity, in this part of the mill, so arranged that all one class or several classes of ore may be sent to be milled, as conditions may require. The ore from the bins is loaded into a 20 cu. ft. car and passed over a Fairbanks registering scale, where the record is made of the total weight of ore delivered to the mill. It is then fed through a 40 in. diameter by 10 ft. long washing trommel, running at 14 rev. per minute, the screen portion of which is arranged with holes 1.5 in. in diameter. The coarse ore from the screen falls on to a 30 in. wide picking belt, from which the hand-picked portion of the high-grade ore is sorted, the low-grade portion on the belt being conveyed and delivered to the crusher, where it is broken to 1.5 in. before passing into the battery ore bin. The ore screened through the trommel flows to a washing trommel 30 in. in diameter by 6 ft. long running at 20 rev. per minute, equipped with 0.5-in. round-hole screen, the oversize from which goes to two jigs, fitted with rolled-slot screen, width of slot 0.115 in.; here the first jig portion of the high-grade ore is collected.

The undersize from this last trommel is conveyed to another trommel, 36 in. in diameter by 9 ft. long, running at 20 rev. per minute, equipped with 3-mm. round-hole screens, and from here the discards go to two jigs, fitted with rolled-slot screen, width of slot 0.040 in.; here the

second jig portion of the high-grade ore is obtained. The undersize from this last trommel, together with the discards from the four jigs, is elevated to a dewatering trommel, 30 in. in diameter by 6 ft. long, fitted with 3-mesh wire cloth screen. From this dewatering trommel the oversize joins that portion of the ore from the picking belt which is destined for the battery, while the undersize after dewatering is sent direct to join the pulp from the battery as it goes to the tube mills. This portion of the ore, representing from 10 to 15 per cent., is the original fines as they come from the mine together with some which may have been produced in the preliminary stages of crushing, and the by-passing of it around the battery in this manner has very successfully and materially assisted the battery work. The water used in the washing plant is kept continually in circulation by a 4-in. diameter centrifugal slime pump, a few pounds of lime being added to the water every day to aid the settlement of slimes, these being collected in two 12-ft. diameter by 6 ft. vats, where after settlement they flow to tube mill pulp. The power necessary to operate this plant is 35 kw. for 9 hr., during which time from 300 to 350 tons is handled.

This part of the operations followed closely along the line of previous sorting and jiggling practice worked by the company and owes much of its success to H. A. Kee and his experience in this work.

The high-grade ore, which is sorted out in this part of the mill, varies considerably in quantity and grade, but an average recovery is as follows, per 100 tons treated:

	Tons	Average Value Oz. per Ton
Hand-picked ore.....	0.662	2,803
First jigs.....	0.265	2,496
Second jigs.....	0.138	2,200
	1.065	2,648.47

This ore is sent to the high-grade ore mill, where it is treated by the cyanide amalgamation process described in R. B. Watson's article, a recovery of 97 per cent. being obtained by amalgamation, and a further 2 per cent. by cyaniding, or a total recovery of 99 per cent. from a 2,648.47-oz. silver ore. The residues, which contain from 8 to 9 per cent. of cobalt, are afterward sold for the value of this metal and 85 per cent. of the silver contents, so that from an ore of the above original head value, only about 4 oz. of the silver value is not paid for.

The ore after being crushed to 1.5 in. in a No. 4 gyratory crusher is transferred on a 20-in. belt conveyor into the mill building, then elevated by a 16-in. bucket elevator into the battery ore bin, which has a capacity of 780 tons. The ore is fed from the bin into the mortars by suspended Nelson feeders.

Battery

The mortar-block foundation, consisting of 846 cu. yd., is of concrete, 81 ft. long by 6 ft. wide on top, with the anchor bolts set in on an incline, and facilities are arranged for dropping the bolts so that a mortar may be easily removed. The battery posts are 12 by 26 in. and 24 by 26 in., set in cast-iron shoes, rubber 0.25 in. thick being placed between shoes and concrete. The mortars are Fraser & Chalmers No. 161 type for rapid discharge; they weigh with steel liners 12,410 lb. each, and have rubber 0.25 in. thick placed between them and concrete.

There are forty 1,500-lb. stamps, arranged five to each cam shaft, and the order of drop is 1, 3, 5, 2, 4, with a set height of 8 in. at 96 drops per minute. The cam shaft is a 7 in. diameter Blanton fluted type and the stems are 4 in. in diameter. The height of discharge is maintained at 1 in. above the level of the dies.

The stamps when new are made up as follows:

	Pounds
Swedish iron stem, 4 in. diameter by 16 ft. long.....	681
Cast-steel tappet, 10½ by 14 in., keys and gib.....	190
Cast-steel head, 9.5 in. diameter by 24 in. long.....	412
Forged chrome-steel shoe, 8½ by 12 in. long.....	254
	1,537

Each battery of 10 stamps is driven by a 40-h.p. motor running at 575 rev. per minute. The motor is placed directly under the ore bin and drives with a 12 in. wide rubber belt to the counter shaft placed below the feeder and mortar floor. This counter shaft runs at 113 rev. per minute and is placed at 11 ft. 7 in. centers from the motor. Drive from counter shaft to cam shaft is by a 12 in. wide 8-ply belt to a 6 ft. diameter cam shaft pulley. The operation of the various battery motors is controlled by individual switchboards arranged side by side, under the battery ore bins.

The battery screens are 18 in. deep and are made of crucible cast high-carbon steel, double-crimped, wire cloth. This quality of screen has been in operation now for three months, and the screens show practically no signs of wear.

Chilled cast-iron liners 1 in. thick in the mortars last but 30 days, while manganese-steel liners last as long as 165 days. Life of shoes is 105 days, equal to 703.5 ton-days, dies being good for 130 days, equal to 871 ton-days.

The power necessary to drive each 10 stamps is 23 kw.

A dilution of about 7 of solution to 1 of ore gives the best results in the mortars while crushing.

The battery feed vat is 20 ft. in diameter by 15 ft. deep, containing

147 tons of solution, and the underside of the vat is located 8 ft. 6 in. above the top of the mortar. The main pipe installed between vat and batteries is 6 in. in diameter, and flanged connections are used between pipes, fittings, and valves to enable the easy cleaning of pipes.

On account of the preliminary desulphurizing treatment which is given to the ore before cyaniding, it is necessary to crush the ore in the battery in a 0.25 per cent. caustic soda solution, with no cyanide in it, 5 lb. of lime being added to every ton of ore as it is placed in the battery ore bin, as being necessary for the settlement of the slime in the collecting vats, enabling a clean solution to be returned for recrushing and classification purposes.

The Cobalt ores are extremely hard and tough and the following table gives some results on crushing and screening capacity:

Battery Screens and Crushing Duty

Stamps in Operation	Mesh per Inch	Size of Wire Inch	Aperture Inch	StampDuty per 24 hr. Tons
Early Practice				
20	8 by 8	0.048	0.077	5.7
20	4 by 4	0.072	0.178	
Present Practice				
20	3 by 3	0.072	0.261	6.7
20	2 by 2	0.092	0.408	

Screen Pulp Grading Mesh

+8	+20	+60	+100	+150	+200	-200 Sands	-200 Slimes
25.1	29.8	17.89	5.93	1.93	1.65	4.28	12.43

Classification and Fine Grinding

The importance of extremely fine grinding was clearly demonstrated in the early experiments, and further experimental work confirmed this. The grinding was then considered on the basis that all the ore, metallic silver included, had to be ground to pass a 200-mesh screen; then this product had to be classified to take out the -200 mesh sands for regrinding and further classification, until there remained only about 15 to 20 per cent. sand, much finer than -200 mesh, in the product delivered to the cyanide plant.

The need for an accurate method to determine the percentage and grading of these sands and slimes was soon apparent and resulted in the provision of a small system of cone classification to replace the earlier practice of hand panning. Three tin cones, respectively 5.5 in., 7 in., and 10.5 in. in diameter at the top, were arranged in series for these tests, with a water dilution vat 8 in. in diameter by 8.5 in. deep located to give a 6-in. head. The pulp to be tested is slowly fed into the first and smallest of this series of cones and the different grades of sands and slimes are recovered from each cone. This device shown in Fig. 5, works fairly accurately, so two of them were installed; thus a constant check could be kept on this work, as the final residues from the cyanide plant almost invariably rise or fall according to the efficiency of the grinding.



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FIG. 5.—ELUTRIATION APPARATUS IN LOW-GRADE ORE MILL.

As an instance of this, when a grading test of the mill pulp delivered to the cyanide plant shows 3 to 4 per cent. +200 mesh and 30 to 35 per cent. sands in -200 mesh, the final residue after cyanide treatment will be about 3.50 to 5.00 oz. of silver per ton. When a grading test of the pulp shows 0.5 to 1.0 per cent. +200 mesh and 15.0 to 20.0 per cent. sands in -200 mesh, the final residue after cyanide treatment will be under 2 oz. of silver per ton of ore.

The necessity for such fine grinding of the ore accounts for the large tube mill and classifier capacity as compared with the number of stamps operating. The classification is obtained in one drag classifier and six Dorr Duplex classifiers, the slime-overflow lips of which were raised 5

in. to give more opportunity for the settlement of the — 200 mesh sands, and prevent them from being carried over with the fine slimes as they overflow to the cyanide plant.

Tube Mills

The four tube mills are 6 ft. in diameter by 20 ft. long, with feed- and discharge-end bearings 20 in. in diameter by 18 in. long. The feed-end bearing or gudgeon is fitted with a removable, hard iron, spiral-grooved liner 9 in. in inside diameter, and to the outside is fastened the feeding device, consisting of a cast-iron spiral scoop, the inside dimensions of which are 6 by 6 in. This scoop picks up from a wooden box the pulp which is to be fed into the mill. The discharge-end gudgeon has a chilled cast-iron screen with 0.5 in. diameter holes in it to retain the pebbles inside the mill. The shell of the mill is $1\frac{9}{16}$ in. thick, and Silex bricks 4 in. thick are used for inside lining. There are two 18 by 18 in. man-holes. The mills run at 25 rev. per minute and are driven by pinion and spur gears of 100 and 15 teeth, 3.5 in. pitch and 12 in. face, from a counter shaft to which the 96 in. diameter by 19 in. face driving pulley is connected through a quill and friction clutch. The weight of the shell of the mill is 9,650 lb. The weight of the two cast-steel heads, $1\frac{1}{2}$ in. thick, is 12,000 lb. The total weight of each mill is 45,375 lb.

The mills are arranged parallel to each other and at right angles to the battery, the driving, shafting, and gears being arranged at the feed end of the mill. Each mill is driven by a 125-h.p. motor, running at 580 rev. per minute, the motor pulley being 28 in. in diameter and 19 in. face and driving to the 96 in. diameter pulley on the counter shaft.

Two of the mills with their motors are located at 19 ft. 4 in. centers and the other two at 24 ft. 4 in. centers, the drive being transmitted through 18 in. wide eight-ply endless stitched rubber belting.

This system of driving has been very satisfactory, none of the belts after 12 months' continuous service having yet been cut or spliced. The power necessary to drive each mill is 85 kw. when they are carrying a pebble load about 2 to 3 in. above the center of the mill. The mills operate in a closed circuit, two of them taking the classified pulp from the battery and the other two taking the classified fine sands for regrinding.

The two coarse-grinding tube mills are charged with flint pebbles and a hard-ore pebble, selected from the hardest portion of the run-of-mine ore, and the average consumption of pebbles in these two mills per ton of ore crushed is about 1.8 lb. flint pebbles plus 2.0 lb. of ore pebbles. The two fine-grinding tube mills are charged with only flint pebbles and the average consumption of pebbles in them per total ton of ore crushed is about 4.3 lb., thus giving a total flint pebble consumption of 6.1 lb. plus 2 lb. of ore pebbles.

The best grinding efficiency is obtained in all mills when the pulp carries about 40 per cent. of solution.

The following data give the particulars of the feed and discharge of the mills when operating on the basis of 244 tons per day:

Two Tube Mills on Coarse Grinding fed by four Duplex Dorr Classifiers, each Classifier handling about 61 Tons in 24 Hr.

Two Tube Mills on Regrinding fed by two Duplex Dorr Classifiers and 1 Drag Classifier

Mesh	No. 3 Mill.		No. 2 Mill		No. 1 Mill		No. 4 Mill	
	Head Sam- ple or Feed to Mill	Tail Sam- ple or Discharge	Head Sample	Tail Sample	Head Sample	Tail Sample	Head Sample	Tail Sample
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
+20	57.02	5.8	58.89	2.90	2.12	0.4	4.46	1.44
40	14.7	5.58	14.74	4.96	1.90	0.92	3.86	0.70
60	5.17	6.04	6.82	7.6	2.44	1.00	5.38	1.56
80	4.26	6.24	4.19	8.96	5.06	7.77	6.60	3.80
100	4.73	9.2	4.10	11.32	12.06	2.74	11.34	10.40
120	3.48	7.6	2.47	6.96	11.14	6.46	2.40	9.80
150	0.30	0.40	0.27	5.0	1.42	0.4	3.92	0.62
+200	3.44	6.86	1.43	8.9	18.40	12.90	18.0	4.38
-200	5.21	19.30	5.28	18.11	41.19	38.27	39.94	38.44
Sand								
-200	1.67	32.18	1.58	24.73	3.11	28.23	3.02	28.16
Slime								
Totals	99.98	99.20	99.77	99.44	98.84	99.09	98.92	99.30

The battery pulp is conveyed to and classified in the first set of four classifiers, the slimes overflowing direct to the slime collecting tanks in the cyanide plant, and the oversize from all four is delivered into the two coarse-grinding tube mills. The table shows the grading of the product fed into these mills.

The discharge from the coarse-grinding tube mills flows into the second set of two Dorr classifiers, where it is again separated into slimes and sands; the slimes overflow into the same slime collecting tanks and the sands are elevated to the two fine-grinding tube mills. The table shows the grading tests of these mills.

The discharge from the fine-grinding tube mills flows into the drag classifier and the above set of two Dorr classifiers; the slimes overflow to collecting tanks and the sands are returned for further fine grinding.

In this system all sands and metallic silver are kept in a closed circuit until they have been ground fine enough to overflow the weirs of the classifiers, and on account of the fine product desired, the weirs were raised and the capacity of these standard classifiers was very much reduced, so as to give more opportunity for settlement.

The best classification is obtained when working with a dilution of about 8 of solution to 1 of ore, and frequent sampling of the slime overflow is necessary to insure that not overmuch fine sands are passed over to the collecting tanks.

Tonnage and Values

All the ore is weighed into the mill over a Fairbanks registering scale, a simple and effective method of obtaining the tonnage. These weights are then checked against the usual method of specific gravity tonnage determination made in the slime plant, and after a seven months' mill run there was a variation of only one-eighth of 1 per cent. in favor of the specific gravity tonnage.

Many moisture determinations have been made on a large scale on the ore as it comes into the mill and the average shows 1.5 per cent. of moisture during the summer months and 2.0 per cent. during the winter months.

The head assay value is taken by an automatic sampler, the slotted pipe of which cuts vertically through the mill pulp, about every 6 min. as it comes into the cyanide plant. The ore in the pulp at this stage has all been crushed to finer than 200 mesh in a caustic soda solution, with no cyanide in it, so that this method insures as correct a sample as it is possible to get.

The residue sample is taken while the filter box is being discharged, a number of cuts of the pulp being taken from each discharge opening and then all mixed together.

On the basis of these determinations a check has been kept on the silver bullion being produced, and although a final clean-up will not be taken until the end of the year, yet already more silver is being produced than the commercial assaying of the ore calls for, which warrants the consideration of the difference between the commercial and the corrected assay values of the ore.

The pulp as it flows from the classifiers in the crushing department into the cyanide plant has a dilution of 11 of solution to 1 of dry slime.

Launders

Launders around the mill are all built of a 2-in. dressed dry white pine.

From battery to Dorr classifier, carrying a pulp ground to a 2 mesh

in a 7 to 1 dilution, 9 in. wide by 7.5 in. deep, inside dimensions, on a 15 per cent. grade. The bottom of this launder is lined with a chilled cast-iron liner $\frac{3}{8}$ in. thick, the wear and tear on which after 12 months' operation has only worn off $\frac{1}{8}$ in. from the thickness.

Oversize from classifiers to tube mill feed, carrying a pulp diluted to 40 per cent. for tube mill grinding, 4 in. wide by 8 in. deep, the bottom being lined with $\frac{3}{8}$ in. thick sheet iron. The launder feeding the coarse-grinding tube mills has a 30 per cent. grade and the one feeding the fine-grinding tube mill has a 23 per cent. grade.

Discharge from tube mills to lower classifiers, carrying the tube mill pulp diluted to about 10 to 1, 6 in. wide by 12 in. deep on a 6.25 per cent. grade, and lined with $\frac{3}{8}$ in. thick sheet iron on bottom.

Overflow from all classifiers to slime collecting vats, carrying an all-slime product, diluted about 11 to 1, 9 in. wide by 8 in. deep on a 4.7 per cent. grade.

Overflow from slime collecting vats to lower battery solution vat, carrying solution, 9 in. wide by 12 in. deep on a 5.5 per cent. grade.

Transferring slimes into any cyanide treatment vat, taking delivery from a 7 in. diameter centrifugal pump of 1,000 gal. per minute, diluted 1.5 solution to 1 slime, 22 in. wide by 18 in. deep on a 3.1 per cent. grade.

Transferring slimes into any cyanide treatment vat, taking delivery from a 4 in. diameter centrifugal pump of 230 gal. per minute, diluted 1.5 solution to 1 slime, 11 in. wide by 12 in. deep on a 3.1 per cent. grade.

Decanted solution from cyanide treatment vats, from a 6 in. diameter decanter under a 13-ft. head, 19 in. wide by 15 in. deep on a 1 per cent. grade.

Cyanide Plant

This part of the mill is placed in a building apart, but connected to the battery and tube mill building. It is arranged in two floors, the upper one containing all the slime collecting and the cyanide treatment vats and the lower floor containing all the solution vats, slime filters, and pumps. The slime treatment vats are shown in Fig 6.

There are on the upper floor:

Three 34 ft. diameter by 13 ft. deep slime collecting vats.

Seven 34 ft. diameter by 13 ft. deep slime cyanide treatment vats.

Two 34 ft. diameter by 13 ft. deep stock slime pulp vats for charging filters.

One 34 ft. diameter by 13 ft. deep barren solution vat.

These vats are placed in two parallel rows, and, with the exception of the solution vat, they are all fitted with a mechanical stirring apparatus, driven by a line shaft placed over the vats on a wooden bridge or trestle. The paddles in the vats are made of 4 by 6 in. pine on edge and

the two longest arms are 27 ft. in diameter and revolve at 8 rev. per minute, giving a speed on the end of 678 ft. per minute; paddles are located at 2 ft. from the bottom of the vat.

These 12 vats are driven by a 125-h.p. motor, and as on an average 8 of them are agitating at one time, the power necessary to drive vats and shafting is 55 kw. Each vat has an average working load of about 140 tons of dry slime plus about 280 tons of solution.

The slime collecting vats are arranged with a circular overflow around the top on the inside, 6 in. wide by 8 in. deep, over which the



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FIG. 6.—SLIME TREATMENT VATS IN LOW-GRADE ORE MILL.

clear battery solution flows into the launder leading to the lower battery solution vat. The bottoms of the vats are connected to a 7 in. diameter and to a 4 in. diameter centrifugal pump for transferring the thickened pulp, and a 6 in. diameter decanter is fitted to the side of the vat.

The battery pulp is run into one of these vats for about 9 hr., collecting about 92 tons (dry weight) slimes, and during this collecting period the excess solution overflows to the lower battery solution vat, from which it is repumped for circulation in the battery solution circuit. When the necessary charge is collected, the pulp is switched to collect in the next vat and in the meantime the slime is settling, excess solution

being decanted until the pulp in the vat represents about 1.5 solution to 1 slime. The pulp is now agitated for about 1 hr., the depth of pulp measured, sampled, and specific gravity determination made for slime tonnage. The specific gravity of dry slimes on this ore is 2.7. The calculation made here, as previously noted, works out at practically the same tonnage as the weighed-in weight of the ore, after due allowance has been made for the addition of lime and tube mill pebbles.

The thickened pulp of 1.5 caustic soda solution at 0.25 per cent. strength and 1 of slime is now pumped to the desulphurizing treatment.

Desulphurizing Process

The problem of working out a successful all-cyanide treatment for the Cobalt ores, in which there is such a varying amount of complex minerals, led to the discovery, during the period of experimental work, of what is now known as a wet desulphurizing process. The details of the reactions involved and the necessity for such a treatment will be obtained by referring to J. J. Denny's article. Briefly explained, the preliminary desulphurizing treatment breaks up the refractory silver minerals when the slime pulp is brought into contact with aluminum in a caustic soda solution, the silver being left in a spongy metallic state readily amenable to cyanide treatment.

The desulphurizing is accomplished by passing the slime pulp through a revolving tube mill, in which there is a quantity of aluminum, and a further treatment is given in a vat lined with aluminum plates, in which the pulp is slowly agitated.

The practical effects of this preliminary treatment on the ores has resulted in the same and sometimes a better extraction being obtained in 48 hr. cyanide treatment than was otherwise obtained in 120 hr. cyanide treatment with no desulphurizing. In some of the ores which contained a greater proportion of the refractory minerals a better extraction of from 1 to 4 oz. per ton is obtained when desulphurized and cyanided, as compared with a cyanide treatment and no desulphurizing.

A tube mill, 4 ft. in diameter by 25 ft. long, lined with 2 in. thick Silex blocks, is used for the first stage of the desulphurizing treatment. This mill revolves at 10 rev. per minute and carries a load of about 4,000 lb. of aluminum ingots, cut up into cubes about 1.5 to 2 in. The slime pulp is fed through this mill at the rate of 14 tons of dry slimes per hour, diluted with 1.5 caustic soda solution to 1 dry slime. The pulp then gravitates into the 34 ft. diameter by 13 ft. deep alkali stock pulp vat, which is arranged with mechanical agitation and lined around the side with aluminum plates. The pulp is agitated in this vat about 24 to 36 hr., or until it is gradually drawn off in about 40-ton charges to the dewatering filter box. On account of keeping the mill cyanide solution

in balance, it is necessary to eliminate as much as possible the crushing caustic soda solution from the slimes before they are transferred into the cyanide vats for treatment, and this is done in a Butters filter plant equipped with 60 leaves, which is capable of dewatering 270 tons of slimes per day, the cake when discharged carrying 26 per cent. alkali solution as moisture.

The slimes after dewatering flow into a 16 ft. by 5 ft. deep pulping vat, where they first come in contact with cyanide solution, being diluted with about 2 of cyanide solution to 1 of slime, a 4 in. diameter centrifugal pump being used for transferring the pulp into the cyanide treatment vats.

Cyanide Department,

There are seven, 34 ft. diameter by 13 ft. deep slime treatment vats, fitted with mechanical stirring arrangement. Each vat has a 6 in. diameter decanter, for draining off the clear settled cyanide solution; they are also fitted with a 6 in. diameter air lift operated by a 0.75 in. diameter pipe with air at 20 lb. pressure.

The slimes are treated in charges of about 130 tons dry slimes in a vat, with a dilution of 2 of solution to 1 of dry slimes in a 0.25 per cent. cyanide solution and 0.20 per cent. alkali, agitation being maintained for 48 to 60 hr. Repeated testing in the mill has demonstrated that equally as good an extraction of the silver values is obtained with a 2 to 1 dilution as with a 3 to 1 dilution. The air lift is operated all the time the charge is being treated, so that there is a possible turning over of the charge about 16 times by the air lift.

After the agitation treatment, the charge is allowed to settle, so that the clear solution may be decanted to the pregnant solution vat. The pulp is then agitated and transferred by a 7 in. diameter centrifugal pump to the 34 ft. diameter by 13 ft. deep cyanide stock pulp vat, in which it is kept agitated until drawn off into the filter box.

A Butters filter plant equipped with 80 leaves handles 35- to 40-ton charges in about 3 hr. each, the slimes being discharged with 26 per cent. of moisture. The alkali and the cyanide filters are arranged alongside of each other, Fig. 7, so that the same operator handles both boxes from the switchboard placed between them. The filter plants are arranged on the semi-gravity plan; a 10 in. diameter centrifugal pump with 12 in. diameter suction and delivery pipes and hydraulically operated valves is connected with the cyanide box for transferring the excess pulp and solution wash. The clear solution from the cyanide filter box is delivered to the pregnant solution vat and the residue slime is dropped into the empty box, discharging by gravity to the residue dump.

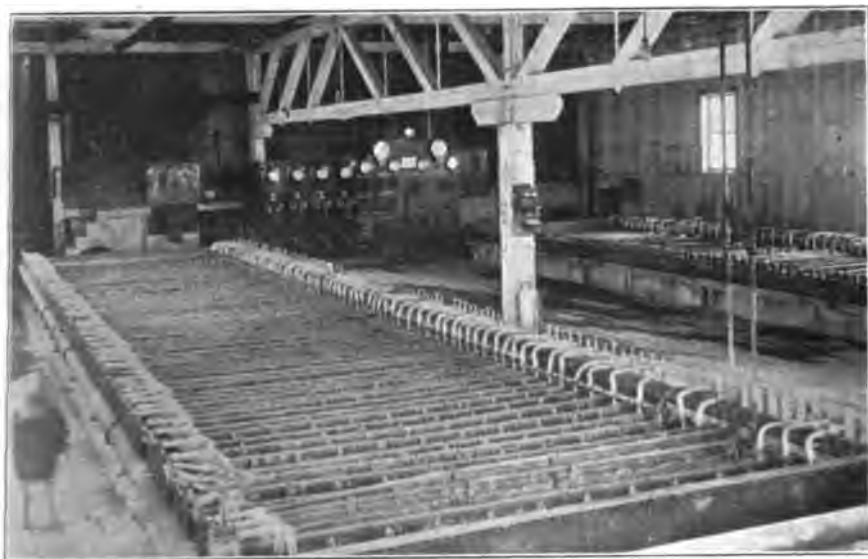
The alkali filter box is connected to an 8 by 10 in. duplex double-

acting piston vacuum pump with a displacement of 340 ft. per minute at 160 rev. per minute. The cyanide box has a 12 in. diameter by 10 in. stroke duplex double-acting piston vacuum pump with a displacement of 770 ft. per minute at 160 rev. per minute.

The pregnant solution vat is 34 ft. diameter by 8 ft. deep and the barren solution vat is 34 ft. diameter by 13 ft. deep.

Precipitation Department.

The original plans of this section of the mill were laid out with the intention of using zinc dust for precipitation and an equipment was in-



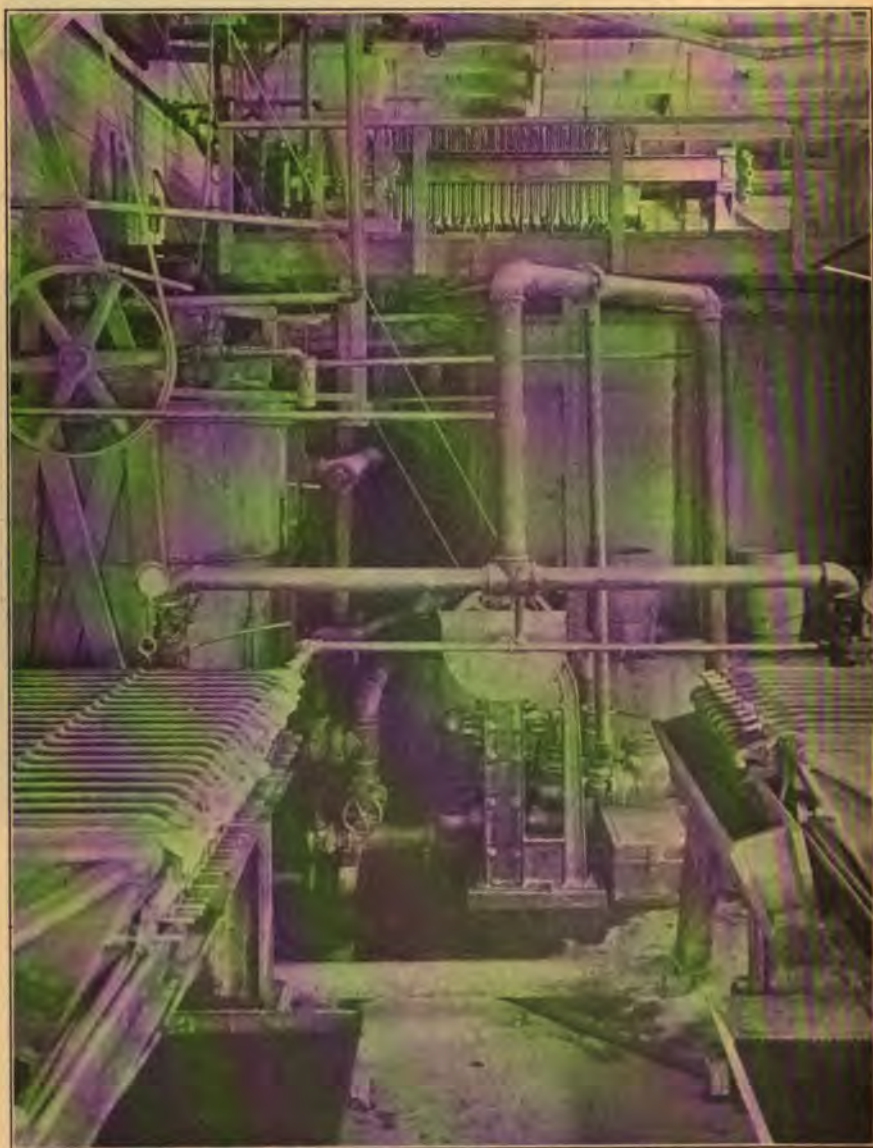
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FIG. 7.—BUTTERS SLIME FILTER PLANT IN LOW-GRADE ORE MILL.

stalled of one 20-frame and one 10-frame 52-in. Merrill precipitation presses with 3-in. frames, together with the other necessary machinery.¹

Before the mill was ready to start, the experimental work on the use of zinc dust as a precipitant had disclosed that the cyanide solutions after precipitation rapidly deteriorated and fouled, so as to lose their dissolving efficiency. The investigation on this subject has been very fully explained in E. M. Hamilton's and J. J. Denny's articles and proves how impossible it would be to use zinc dust and get good results. After considering various other methods of precipitation, it was decided to use aluminum dust as the precipitant and modify the equipment accordingly.

The practical benefits gained by this change are:



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FIG. 8.—ALUMINUM DUST PRECIPITATION PLANT IN LOW-GRADE ORE MILL.

No fouling of cyanide solutions, with a corresponding reduction in dissolving efficiency.

The working mill cyanide solutions are in a more active condition to dissolve silver than if they were freshly made up solutions which had not yet been used, showing in their favor an increased dissolving power of 0.35 oz. of silver per ton of ore.

A regeneration of 0.608 lb. of cyanide per ton of solution precipitated, equal to about 1.67 lb. of cyanide per ton of ore treated, or 408 lb. per day.

The recovery of silver precipitates averaging about 27,000 oz. per ton, or about 93 per cent. silver.

The pregnant solution is pumped to the precipitation room by a 6 by 9 in. vertical triplex pump, running at 54 strokes per minute, where it is clarified in a sand filter before flowing to the special tank arrangement for mixing the aluminum dust in the cyanide solution. It is then pumped into the precipitation presses by another 6 by 9 in. vertical triplex pump. The 20-frame press takes about four days to fill up with precipitates when handling about 550 to 600 tons of solution per day with a head assay running about 8.25 oz. and a tail assay 0.10 oz. The aluminum dust consumption over a nine months' period averages about 0.556 lb. per ton of ore treated, or 1 lb. (avoir.) dust = 45.26 oz. (troy) silver precipitated, or 1 lb. (avoir.) dust = 3.104 lb. (avoir.) silver precipitated. The precipitates are sent to the refinery, where they are melted and refined in a reverberatory furnace, as described in R. B. Watson's article, and eventually shipped as bullion at 997 to 999 fine.

Fig. 8 shows the precipitation plant.

For the aeration of the cyanide treatment solutions and for use on filters and air lifts, there is installed an 18.25 in. diameter by 12-in. stroke belt-driven air compressor, with a piston displacement of 627 cu. ft. of free air per minute at 20 lb. pressure, running at 180 rev. per minute.

The heating plant is of the gravity type and is located 80 ft. away from the main mill building, the boilers being placed so that the water level in them is 5 ft. below the lowest floor level of the mill. There are two horizontal multitubular boilers, 72 in. in diameter by 16 ft. long, working at from 0 to 10 lb. steam pressure, with a 10 in. diameter steam line and a 5 in. diameter return water line between the boiler shed and mill building.

	Radiators	Heating Surface Square Feet
Mill building.....	57	8,092
Washing plant.....	13	1,971
Vat shed.....	4	251
Total.....	74	10,314

In addition to this, there is about 40 per cent. more heating surface in all the distributing steam pipes around the mill.

This heating plant has maintained an average temperature of about 60° F. in the coldest weather, which is sometimes down to 40° below zero.

Extraction

The following figures represent the average extraction obtained from a run-of-mine ore of 54 oz. of silver per ton, in the combined metallurgy of the high-grade and low-grade ore mills:

	Heads per Ton	Total Silver	Extraction	Average Residue per Ton	Total Residues
79 tons of	2,648.47 oz.	= 209,229.13 oz.	at 99%	26.484 oz.	= 2,092.29 oz.
7,320 tons of	26.00 oz.	= 190,320 oz.	at 92%	2.080 oz.	= 15,225.60 oz.
7,399 tons	54.00 oz.		95.66%	2.34 oz.	

To this will be added the further recovery of 85 per cent. of the silver, made on the sale of the above 26.484 oz. of residue.

The working mill costs are here represented in the percentage that the various most important expenses bear to the total cost.

	Per cent.
Labor.....	28.207
Cyanide.....	19.943
Electric power.....	14.542
New construction supplies.....	5.586
Aluminum dust.....	4.761
Aluminum ingots.....	4.709
Caustic soda.....	1.811
Aluminum plates.....	1.401
Refinery fluxes, fuel oil, coke, etc.....	1.332
Pebbles.....	1.284
Battery supplies.....	1.013
Lime.....	0.579
Sundry supplies.....	14.832
	100.000

*Operating Costs per Ton of Ore Treated; Average for the Months of July,
August, and September, 1913*

Costs calculated on basis of 7,320 tons treated per month

	Labor	Sup- plies	Power	Work Shops	Totals
SUNDRY COSTS PER TON					
Meyer receiving plant	\$0.049	\$0.002	\$0.003	\$0.001	\$0.055
Aerial tram line	0.059	0.004	0.003	0.009	0.075
Surface tram line	0.073	0.045	0.005	0.027	0.150
Washing, jigging, and picking plant	0.138	0.042	0.006	0.024	0.210
Totals	\$0.319	\$0.093	\$0.017	\$0.061	\$0.490
New construction	\$0.036	\$0.209	.....	\$0.065	\$0.310
MILLING COSTS PER TON					
Preliminary crushing to 3 in.....	\$0.074	\$0.004	\$0.006	\$0.002	\$0.086
Secondary crushing, conveying, and elevating	0.028	0.015	0.005	0.001	0.049
Battery	0.077	0.053	0.095	0.013	0.238
Tube mills and classifiers,	0.096	0.103	0.282	0.019	0.500
Slime collecting, desulphurizing, and transferring	0.042	0.294	0.022	0.008	0.366
Alkaline, filtering and transferring ..	0.070	0.017	0.023	0.004	0.114
Cyanide treatment and transferring ..	0.120	0.793	0.071	0.020	1.004
Cyanide filtering and discharging ..	0.072	0.041	0.034	0.015	0.162
Clarifying solutions and precipita- tion	0.050	0.221	0.008	0.005	0.284
Drying, melting, and refining	0.074	0.050	.....	.....	0.124
Water supply.....	0.001	0.001	0.021	0.002	0.025
Totals	\$0.704	\$1.592	\$0.567	\$0.089	\$2.952

Electrical Power

In a mill where the average power costs represent about \$4,000 out of a total working cost of about \$28,000 per month, it was advisable to arrange the installation so that as high an efficiency as possible might be obtained.

The installation was so planned that each machine should be of the correct size to carry its load, and thus obtain the highest efficiency and power factor.

As a measure of the success obtained in this respect it may be stated that the power factor of the mill averages 82.5 per cent.

Original Motor Power Distribution

	Motors	Horse Power	Rev. per Minute	Total Horse Power
Washing Plant: operates 6 days of 9 hr. each, per week:				
Main drive.....	1	40	850	
Aerial tram line.....	1	15	565	
Surface hoist.....	1	30	720	
Elevator hoist.....	1	10	900	95
Battery:				
Battery drive.....	4	40	575	
Return solution pump.....	1	40	575	
Elevator ore bin.....	1	10	1,120	
Conveyor belt.....	1	5	1,800	215
Tube Mills:				
Mill drive.....	4	125	580	
Lower classifiers.....	1	5	1,120	505
Treatment:				
Agitating tanks.....	1	125	485	
Circulating slime.....	1	35	855	
Circulating desulphurizing.....	1	20	690	
Alkali pump to cyanide tanks...	1	20	690	
Experimental plant.....	1	2	1,800	202
Two Filters:				
Filter box—cyanide.....	1	80	870	
Filter box—alkali.....	1	35	855	
Vacuum pump—cyanide.....	1	10	570	
Hydraulic valves.....	1	1	1,200	126
Precipitation.....	1	10	570	10
Water Service:				
Centrifugal pump.....	1	25	1,800	25
	27			1,178

Cost of installation, \$24.15 per horse power of motors

Cost of Electrical Installation

Motors, switchboards, wiring, etc., and labor.....	\$26,532.86
Electric lighting of mill.....	1,635.61
	\$28,168.47
Extra wiring, poles, etc., for the Peterson Lake pumping plant, located about 1,560 ft. from the main buildings.....	250.00
	\$28,418.47

Power is received at a pressure of 11,000 volts and is transformed to the working pressure of 550 volts in a substation situated 150 ft. from the

main building. A three-phase overhead line from this substation feeds the main switchboard, which is placed on the tube mill floor, this position being about the center of power consumption.

From the main board, feeders are carried through suitable links and disconnecting switches to the various motor control boards.

The motors are all three-phase 550 volts 60-cycle Canadian Westinghouse type G.M. machines. The "squirrel cage" rotor was selected on account of its ruggedness and simplicity. The average full-load efficiency and power factor for each class of these machines was found after careful testing to be:

	Efficiency, Per Cent.	Power Factor, Per Cent.
125-h.p. class.....	91	89.6
80-h.p. class.....	89	88
40-h.p. class.....	88.3	86.9
35-h.p. class.....	87.5	83.6
15-h.p. class.....	85.8	85.5

Each motor is provided with a control panel upon which are mounted a three-pole automatic oil circuit breaker, an auto-starter, fitted with no-voltage release, an ammeter, and a serviceable inverse time-limit relay in the form of fuses and a double-pole spring tumbler switch, inserted across the circuit breaker tripping coil terminals. This relay is used for starting duty only, and in conjunction with the no-voltage release on the auto-starter, renders the gear practically "fool-proof." The motor control panels, 1 ft. 6 in. wide by 6 ft. high, are grouped to make switchboards of convenient size, and are so placed that the machines which they control may be easily seen from them.

The main switchboard is equipped with an automatic three-pole oil circuit breaker, controlling the entire mill supply, a voltmeter, an ammeter, an integrating wattmeter, and a graphic recording wattmeter. The wiring of the graphic wattmeter is so arranged that a record of either the total mill load or the load of any individual motor may be obtained.

All wiring within the mill is carried in steel conduits. The average total load on the mill amounts to 690 kw. The recording wattmeter registers a variation of less than 5 per cent. from this figure from day to day, on the day load.

Much credit is due to W. H. R. Burrows, the company's resident engineer, for the excellent installation and high efficiency obtained in this power service.

In conclusion, I wish to acknowledge the encouragement and assistance of R. B. Watson in the many difficulties that developed before everything was satisfactorily worked out, and his permission to publish the data in this article; also to put on record the good work done by Mr. Hamilton and Mr. Denny both during the experimental work and during the starting up of the mill.

TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS
[SUBJECT TO REVISION]

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the New York meeting, February, 1914, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Apr. 1, 1914. Any discussion offered thereafter should preferably be in the form of a new paper.

The Need of Uniform Methods of Sampling Lake Superior Iron Ore

BY C. B. MURRAY, CLEVELAND, OHIO

(New York Meeting, February, 1914)

"Our experience from time immemorial has been that the furnace sampler and analyst usually find one or two, and sometimes more, points less iron than the Lake Superior shippers, but, fortunately, their contracts are 'iron bound'; and, generally speaking, analyses at this end are practically useless, for we are obliged to settle on a basis figured out to a half dozen decimals, and, as a rule, without recourse in the event of flagrant discrepancies between the two analysts."

The above is an extract from a letter received by the writer of this paper from the President of an iron company, discussing the question of sampling. It so well expresses the opinion of many blast-furnace owners and managers that it seems a suitable text for a discussion concerning the need of uniform methods of sampling.

If all railroad cars were loaded the same, if all stock piles were the same shape, and if ore was received regularly each day, the problem of sampling would be comparatively simple. The conditions, however, vary widely at different places, and at the same place from day to day, and it is probably impossible to determine upon any one method of sampling which will apply at all times and in all cases. However, it would seem as though some general principles might be suggested which would tend to overcome these wide differences in samples of the same thing.

The sampling of a cargo of iron ore begins at the breast of ore in the mine. The ore is sampled from the mine cars, from the stock piles, and from the railroad cars at the mines. At the lower Lake ports the ore is practically all sampled from the boat, occasionally from railroad cars. At the furnaces, the ore is nearly all sampled from railroad cars and occasionally from stock piles.

During the last ten years, sampling at the mines has been very much improved. The question has been very generally discussed, and each year has seen some improvement. The United States Steel Corporation, in 1908, took a very decided stand in this matter. After carefully looking into the various methods of sampling used at their own mines, a committee recommended certain methods of sampling, differing somewhat at the producer's and at the consumer's end. These methods were adopted

and have since been used at all the mines and furnaces controlled by the Corporation.

These methods, or modifications of them, have been adopted by some of the other mines in the Lake Superior region, but many of the mines are as yet paying but little attention to sampling from a scientific standpoint. Last summer Benedict Crowell read a paper before the Lake Superior Mining Institute on Methods of Sampling at Lake Superior Mines. This paper brings out very clearly the need of some standard method of sampling at the mine, and suggests the details of such a method.

Prior to 1907, there were several methods of sampling in use by the Cleveland chemists in sampling iron ore at the lower Lake ports—some favoring small samples, others favoring large samples; some taking one round when the boat was half unloaded, others taking three rounds, at certain stages of the unloading. These different methods of sampling resulted in discrepancies in results, particularly if the ores were mixed.

At the beginning of the season of 1907, the Cleveland chemists adopted a standard method of sampling, which was a step in the right direction. This standard method has been broadened and improved from year to year, and, while it is not yet perfect, it has shown itself capable of giving accurate results if conscientiously carried out. The method is as follows:

A standard sample shall be taken from all cargoes, the weight of the sample varying with the size of the cargo.

The sample shall be taken with a galvanized iron scoop 3.5 in. wide, 2.25 in. long, and 1.25 in. deep, the handle 8 in. long; and with a hammer 12 in. long (the scoop holds approximately 0.5 lb.).

It shall be the aim to take an equal bulk of ore from every point selected. When a lump is encountered, a portion shall be broken off equal in bulk to a scoopful of soft ore. In sampling cargoes, no sample shall be taken from the original outside surface on account of the presence of foreign matter and an undue proportion of fines.

If the surface to be sampled has been exposed to rain or sun long enough to materially alter the amount of moisture present, the sample shall be taken about 3 in. below the surface.

In order to keep the size of samples within reasonable bounds and to gauge this size to the size of the boat, the sampler shall, on cargoes up to 4,000 tons, begin sampling at a convenient point at the bottom of the face of the ore, and shall take one standard scoopful every two scoop lengths up the face of the ore to the top, and then shall move four scoop lengths to one side of the starting point before again sampling vertically. He shall continue in this manner, keeping the above distances, around the face of the ore to the place of beginning.

On cargoes from 4,000 to 6,000 tons, he shall use the two scoop lengths for vertical distances up the face of the ore, but move six scoop lengths horizontally.

On cargoes over 6,000 tons, he shall use the two scoop lengths for vertical distances up the face of the ore, but move eight scoop lengths horizontally.

In case of split cargoes, horizontal spacing to be according to the tonnage of each individual ore as specified in the preceding paragraphs.

At convenient stages of unloading, the sample shall be mixed and quartered. This must be done each time exactly alike, by breaking down to 0.5 in., mixing and quartering twice, thus preserving the proper proportion of the whole sample.

If in the final quartering the last two quarters exceed a can full, the ore shall be quartered and one quarter rejected.

The sample may be quartered on the vessel, or may be taken to some other place suitable for that purpose. Samples must be shipped in standard cans.

Sampling of Soft Ore

The sampler shall enter any hatch and begin sampling when the unloading machines have exposed 5 or 6 ft. of the face.

The sampler shall then enter the next hatch working, and proceed to sample in the same way, and so continue in every working hatch.

The sampler shall then begin over again in the hatch in which he first started and continue the sampling in all the working hatches, provided there has been sufficient ore removed in such hatches since the faces were sampled to expose fresh ore.

The sampler shall continue this method in each hatch worked until there is less than one-tenth of the ore left.

In sampling horizontal surfaces, as in boats where scrapers are used, the sampler shall sample every two scoop lengths lengthwise of the boat, the spaces between the lines of sampling to be 4-6-8 scoop lengths, according to the tonnage, as described before.

Sampling of Hard Ore

In sampling hard lump ore, the sampler shall begin sampling and use the same spacing as defined for soft ore, using hammer lengths instead of scoop lengths. At each point sampled he shall take lump or fine ore equal to 1 cu. in. In taking this cubic inch, the sampler shall take an average from the lump ore from which the cubic inch is broken.

Moisture Sample

The moisture sample shall be taken from the standard sample in the following manner:

When as many cans of ore have been filled as the stage of unloading will permit, the lump ore shall be broken up quickly and the entire amount thoroughly mixed and flattened out into a circular pile. The pile shall

then be marked into quarters, and one of the quarters divided into two parts by a line from the center to the outside of the pile.

The whole of one of the half quarters so marked off is to be placed at once in a tightly covered receptacle to be a portion of the moisture sample. The other half of the quarter together with the whole of the opposite quarter is to be rejected.

The remainder of the pile is to be thoroughly mixed and flattened, and two opposite quarters rejected. The remainder of the ore is to be put one side for a portion of the standard sample.

By this method of procedure, one-eighth of the entire sample taken will go into the moisture sample.

At the end of the sampling, the accumulated moisture sample is to be taken out of the tightly covered receptacle, quickly mixed and flattened out, divided into eighths and enough eighths taken to fill the standard moisture can.

In case of hard ores or small tonnages of soft ore, the proportion set aside for the moisture sample shall be increased so that at least one can of ore shall remain for the final moisture sample.

The moisture determination is made by drying the whole of the final sample at a temperature not over 212° F. until there is no loss in weight. The loss of weight divided by the amount of ore taken will give the percentage of moisture.

Variation in Methods of Sampling

It is at the various furnace plants where Lake Superior iron ores are used that we find the widest variation in methods of sampling.

Some months ago the writer sent out a circular letter to about 30 furnace plants, asking for a description of their method of sampling. It seems worth while to give the replies from a number of these plants and from these replies a conclusion can be drawn as to the need of some uniform method of sampling at the furnaces.

Plant A: "We send a man out with a bucket and take a small portion out of six different places in each car. We do this on every car that we get out of a cargo, and from a cargo of about 7,000 tons we get about enough out of it for a sample to fill a 12-quart can."

Plant B: "Cars as a rule are loaded with two piles of ore, approximately 25 tons at either end of the car. The sampler cross-sections roughly each pile and takes four small shovelfuls off each, or eight shovelfuls from each car. These car samples are collected in one large pile until the entire cargo is received. The entire pile is passed through a crusher and crushed to 3/4-in. screen. Next the entire sample is coned and quartered down to a bucketful, or approximately 15 lb., which is taken to the laboratory."

Plant C: (The description of this method was preceded by a mathematical demonstration of finding the volume of a cone 4 ft. high and 6 ft. base and showing that one-half the volume of the cone is in the lower 0.826 ft. of the height.) "The ore in the cars is usually in three piles. These piles are cone-shaped, with apex of the cone

rounded off. The piles are sampled as follows: One sample taken near the floor of car, one sample taken near the top of pile, and another sample taken at one-third the height of pile. If at the first place the ore is all lump, a measured trowel of lumps broken from the different sized lumps is taken. Each pile in the car is sampled in the same manner, or nine trowels full taken to a car."

Plant D: "When a sample is desired, it is usually taken from the filling barrow, using a hammer and a small shovel so as to keep the proportion of fine and coarse ore as it is. This sample averages about 20 lb."

Plant E: "We sample from 30 to 40 cars in each cargo as follows: When the ore is loaded in the car in one pile we take a scoop at each corner about 2 ft. up from the bottom and about the same distance in from the sides. Then a scoop on each side at the top toward the sides. The lump is sampled according to the amount in each car, judging as near as possible the proportion of lump to fine. When the ore is loaded in two piles the sample is taken the same way, except that we take one scoop at the top."

Plant F: "The sampling from cars, from five to seven buckets full, averaging 40 to 50 lb. to the bucket, are taken from each cargo from cars and mixed and quartered down to about 30 lb. We sample across the car every 2 ft., taking a scoopful, and then lengthwise, measuring 5 ft. for each transverse line of sampling."

Plant G: "Our method of sampling, we presume, is similar to that of the average small furnace plant; that is to say, with a hammer and trowel, we go over the cars, remove the surface, so as to avoid any contamination of foreign matter, and when possible digging a hole down through to the bottom of the car, and estimate the percentage of coarse and fine therein and take samples accordingly."

Plant H: "Our method of sampling has been to have the man go over the car and take samples from all parts of the car, pulverise and thoroughly mix same."

Plant I: "In view of the fact that we mine our own ore and the question of sampling same at the furnaces is not a very important matter, I do not think we would be interested in adopting any uniform method."

Plant J: "On arrival of a train load of ore a sampler goes over each car pretty carefully with the aid of a hammer and small shovel, and after selecting a few pounds from 8 or 10 cars, the material is taken to the laboratory and put through a regular course of quartering and simmering down to the desired quantity."

Plant K: "We have no regular method of sampling."

Plant L: "Sampling at our furnaces is all done as cars are unloaded. A bucketful of ore is taken from each car, thereafter usual laboratory method follows."

Plant M: "In sampling cars, we zig-zag across the top of the cars, taking samples at equal distances. Wherever we have the chance, we drop the bottom of the cars and then sample the two remaining ends of the cars, as this gives us a sloping surface from top to bottom of cars."

Plant N: "Our practice in taking samples from cars is to lay off the surface with an imaginary line in squares and to take as uniform a sample from each as possible."

Plant O: "Each car is sampled at 40 different places, due care being taken that the lump ore represents the same ratio in the sample as exists in the ore itself. The size usually taken from the lump is that of an English walnut, although this is governed by the size of the lumps, and the fine ore is sampled so as to be in proper proportion. In case of gangue, a piece is taken, the amount depending upon the relative amount present."

Plant P: "In sampling ore from cars we use a bucket. Starting at one end of the car or the left side, we go the entire length of the car, breaking the lump and taking some of the inside and outside, also digging down three times and getting the fines. Then sample the center and other side of the car, taking samples 3 ft. apart. We usually have 3 quarts to represent a car."

Most of the other replies showed that an attempt was being made to sample each car in a uniform way; but in all of the methods, the amount of lump and fine taken was left more or less to the judgment of the sampler.

And yet the results of these samplings are compared with the samples of the cargo taken at lower Lake ports, where two or more men have perhaps sampled continually by the standard method for 12 to 18 hr. If the analyses vary widely there is a complaint, and usually the furnace manager insists that his sample is the correct one. It is remarkable that there are not wider differences in the analyses of the two samples, and until more uniformity in taking samples at the furnaces is adopted there will be these wide variations.

Theoretically, sampling is capable of definite mathematical demonstration. In practice, however, we are confronted with some difficulties in attempting to sample by mathematical formulæ.

First, piles of ore vary widely in size and shape. While they may, in general, approach a cone shape, it is rarely that they come near enough to this definite shape to use the formula of cone-volumes in sampling.

Secondly, sampling as a rule is done by uneducated men, to whom formulæ are unknown, and whose judgment as to percentage of lump and fine ore in sight is not infrequently biased by the known wishes of their superiors. Again, the judgment of any two men is liable to vary widely in estimating the amount of lump and fine in a pile of ore; and, furthermore, the proportion of lump and fine in sight may be, and often is, quite different from the proportion in the whole pile.

In my opinion, a mechanical sample is much to be preferred to a judgment sample, especially when the sample represents a considerable amount of ore. Ore as received in cars at furnace plants has been loaded by a grab bucket, in nearly all cases. This method of loading, of itself, tends to mix the ore so that a proper sample from the surface is fairly representative of the whole car.

The jolting motion of cars in transit may perhaps, in some cases, cause a rearrangement of the lump and fine and bring a little more lump to the surface than is the proper proportion. But in sampling a number of cars from the same cargo I do not believe that this will make any material difference.

A Suggested Method for Sampling Cars

I suggest the following method for sampling cars, which I believe could be used in nearly all cases to get a representative sample, whether there be one, two, or three piles of ore in the car. Starting at a point 1 ft. from the end of the car, move in a straight line lengthwise through the middle of the car over the piles of ore, taking equal bulks of ore every 3 ft. Measure these distances, and at the designated point dig about 4 in. below the surface and take a measured bulk of either lump or fine, which-

ever is encountered. A scoop holding about 0.5 lb. of ore could be used, with a handle about 12 in. long, and the scoop may be used for measuring the distances. Or a measuring stick of the right length could be used, without inconvenience to the sampler. This method of sampling could be elaborated, if thought necessary, by going across the car twice more on lines about two-thirds the distance from the center of the car to the side of the car. This, of course, touches the ore in three times as many places, and in the case of mixed ore would tend to give a more representative sample. In a majority of cases, however, in my opinion, it would not be necessary.

The most general objection raised at furnace plants to sampling by measuring distances and taking samples from a number of places is that they do not have the time. At the smaller plants, the sampling is generally done by a laborer who has other work to do, either about the plant or in the laboratory, such as crushing or cleaning up. This objection brings up the point of the value of sampling at the furnace. Is it of any particular value, and if it is, why should it not be done in some reliable way?

I take it that at most plants the ore is sampled chiefly for two reasons: first, to check up the Cleveland chemists; and secondly, to use the analysis of the sampling to burden the furnace. In either case, accuracy is wanted. Why not, then, make a business of sampling?

Analytical results can be redetermined, and if in error can be corrected. After the sample is taken, however, in a majority of cases, no resampling can be done in a satisfactory manner. It would seem then a very self-evident fact that the sampling should be done right, and to do it right requires time and attention, both of which cost money.

I am making this plea for good sampling and suggesting a method of taking samples with the hope that I can bring out some ideas along these lines and all—mines, Cleveland chemists, and furnace interests—get closer together and work more in harmony.

As soon as we can do this, such opinions as are expressed in the opening paragraph of this paper will be removed.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the New York meeting, February, 1914, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Apr. 1, 1914. Any discussion offered thereafter should preferably be in the form of a new paper.

The Work of Crushing

BY ARTHUR F. TAGGART,* NEW HAVEN, CONN.

(New York Meeting, February, 1914)

A GENERAL awakening of interest among mill men concerning the mechanical efficiencies of their crushing machines is evident from a perusal of the recent files of mining publications. Considering the large part of the power bill which must be debited to the crushing department, such interest is natural. When, however, the articles on the subject are read, the only statement upon which the writers agree is that fine grinding consumes a large amount of power, and that the machine which, from a concentration standpoint, offends as a slime producer is, for that reason, a serious offender in wasting power. When the mill man attempts to find a method for measuring the power wasted, or to compare the efficiency of one machine with that of another for the same work, he is confronted with a choice of methods which lead to conflicting results.

There are two reasons why the work of crushing is not more generally understood. In the first place, experimental data are difficult to obtain; and in the second place, before these data can be put in general form certain assumptions must be made. A difference in these assumptions by different investigators has led to conflicting conclusions. This conflict has resulted in the proposal of two laws. The first of these is the so-called Rittinger's law, which is variously stated as follows:

"The work of crushing is proportional to the reduction in diameter."—R. H. Richards: *Ore Dressing*, p. 304 (1903).

"The work required to crush rock is very nearly proportional to the reciprocals of the diameters crushed to."—A. Del Mar: *Engineering and Mining Journal*, vol. xciv, No. 24, p. 1129 (Dec. 14, 1912).

"The work done in crushing is proportional to the surface exposed by the operation, or better expressed for this purpose, the work done on a given mass of rock is proportional to the reciprocal of the diameter of the final product, assuming that all the mass has been reduced to one exact size, which is only theoretically possible."—A. O. Gates: *Engineering and Mining Journal*, vol. xcv, No. 21, p. 1039 (May 24, 1913).

Of this law as variously stated above H. Stadler says: (Grading Analyses and Their Application, Author's Reply to Discussion, *Transactions of the Institution of Mining and Metallurgy*, vol. xx, p. 426 [1910-11]).

* Non-member. Instructor in Mining Engineering, Hammond Laboratory, Sheffield Scientific School, Yale University.

“ many mining engineers still have blind faith in an old blunder which, under the name of Rittinger's law, has been thoughtlessly reprinted and carried on in edition after edition of mining books since the days of the 'Dark Ages' (1850). This 'law' is a myth which has never been recognised by science, and it is unfair to Rittinger's memory to connect his name with what is clearly nonsense, the currency of which, in the mining world, is due either to misunderstanding or the error of a translator. All that Rittinger himself really said on the laws of crushing, in his famous book on ore-dressing, fills barely two out of about 600 pages, and in these two pages he says clearly: '*the increase of the surfaces exposed is directly proportional to the force required for reducing.*' (These words are also in the original text printed in italics.) As Rittinger goes on to say: 'and therefore also to the work absorbed in effecting the separations,' it may certainly be taken for granted that he supposed the force acting in the fracture planes themselves. Now, this may be conceivable for chemical, electrical, thermal actions and reactions, but not for external forces as applied in mechanical crushing. . . . Had Rittinger stated that the increase of surface is proportional both to 'force' and to 'work done,' he would have been guilty of mistaking 'force' and 'work done' as identical. Rittinger's law, therefore, simply states the proportion of the increase of surface to the *force* required in crushing and not also to the *energy* absorbed, which, in conformity with Kick's law, varies as the volumes.”

Kick's law is stated as follows:

“The energy required for producing analogous changes of configuration of geometrically similar bodies of equal technological state varies as the volumes or weights of these bodies.”—H. Stadler: *Grading Analyses and Their Application, Transactions of the Institution of Mining and Metallurgy*, vol. xix, p. 478 (1910-11).

The writer has made a careful analysis of the proofs of the previously quoted authors and has come to the conclusion that the work of crushing is proportional to the volumes of the particles crushed, according to Kick's law; and not to the new area produced, as stated in Rittinger's "law." The reasons for this conclusion follow.

Kick's law is unquestionably correct for all substances where the changes of configuration are within the elastic limit. For perfectly elastic substances the statement holds true to final rupture, and for substances almost perfectly elastic, such as rock, the law is a very close approximation of the fact.

The behavior of structural materials under stress has been widely investigated. The accompanying phenomena are well understood and the laws controlling them are universally accepted. Briefly stated, these laws are:

Within the elastic limit of any substance the force required to produce a given deformation is directly proportional to the area of the transverse section.

The amount of deformation within the elastic limit is directly proportional to the length of the specimen and to the force applied.

The work done in producing a given deformation is the product of the average force by the distance through which it acts.

These laws apply both in tension and in compression.

If, now, we examine the behavior under stress of some highly elastic substance, the results of the examination can be plotted according to the following characteristic curves:

Fig. 1 is a force-area diagram for a given deformation within the elastic limit of the substance. The straight line represents, of course, the direct proportion between transverse area and the force required to produce deformation.

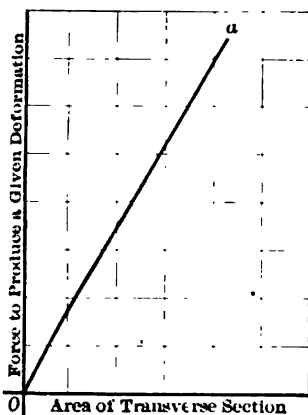


FIG. 1.

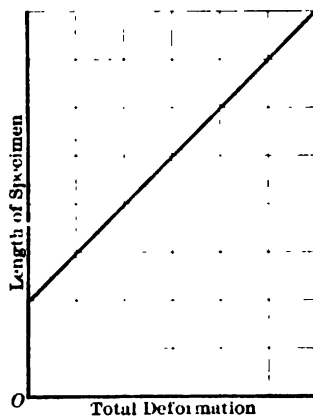


FIG. 2.

Fig. 2 represents the relation, within the elastic limit, between length of specimen and total deformation under a given load. The straight line is here the graphical representation of the law that the deformation under load is, within the elastic limit, directly proportional to the length of the specimen.

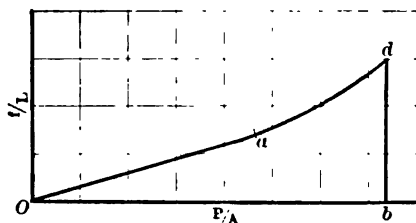


FIG. 3.

The phenomena represented by these curves are typical of all elastic substances both in tension and in compression.

Fig. 3 gives the force-deformation diagram for a highly elastic substance. The portion of the curve, Oa , represents the behavior of the material within the elastic limit. This portion being a straight line, the conclusion is that deformation is directly proportional to the force exerted, through this portion of the curve. The point a marks the elastic limit of

the material. The point d marks final rupture. From a to d unit deformation increases much more rapidly than unit stress. The total work per unit of volume to produce rupture is the area $Oadb$.

The preceding statements may be mathematically expressed as follows:¹

Within the elastic limit

$$f = \frac{PL}{AE}$$

$$W = \frac{Pf}{2} = \frac{P^2L}{2AE} = \frac{A^2S^2L}{2AE} = \frac{S^2}{2E} \times AL$$

When $\frac{P}{A} = S$

If, to simplify the mathematics of the demonstration, we assume the particle under load a cube of edge D , then $A = D^2$, $L = D$, S^2/E is an assumed constant, and

$$W = \frac{S^2}{2E} \times D^3$$

or the work of deformation is proportional to the volume of the particle deformed.

For the maximum unit stress within the elastic limit

$$W = \frac{e^2}{2E} \times AL$$

or the work of deformation, at the elastic limit, is proportional to the volume of the particle deformed.

It is evident from the curve, Fig. 3, that the nearer to a rupture occurs, the greater the ratio of work done within the elastic limit will be to the total work necessary to produce rupture. If a substance fractured imme-

¹ The following notation applies throughout the mathematical discussion unless otherwise noted:

W = Work.

e = Maximum unit stress within the elastic limit.

f = Deformation.

L = Length of body.

A = Area of transverse section.

S = Any unit stress within the elastic limit of the substance.

P = Units of force.

D = Edge of original or unit cube. The cube is chosen for the shape of the particle under discussion for the purpose of simplifying the mathematical development.

U = Ultimate unit stress to produce fracture.

n = Any number.

d = Edge of smaller cubes resulting from crushing.

E = Modulus of elasticity.

diately on reaching its elastic limit, the work would be represented directly by the formula

$$W = \frac{e^2}{2E} \times AL$$

The more highly elastic the substance, the more closely does the work done in rupture approximate the above formula. Thus for highly elastic

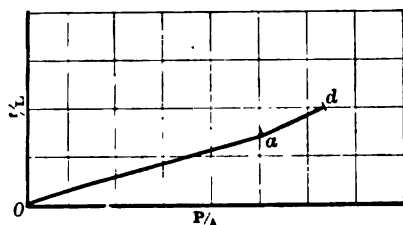


FIG. 4.

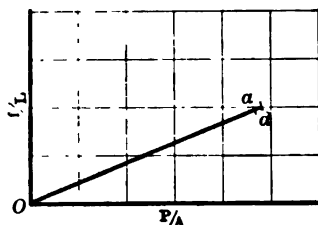


FIG. 5.

steels the force-deformation diagram is as shown in Fig. 4, and for hard rock the diagram becomes as shown in Fig. 5.

The conclusion, then, is forced upon us that the work of crushing a piece of rock is very closely represented by the formula

$$W = \frac{e^2}{2E} AL$$

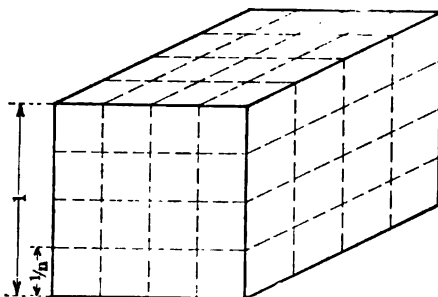


FIG. 6.

If we examine the proofs of Del Mar, Gates, and Professor Richards we find that the distance factor is neglected and that the formula for work takes the form

$$W = KP$$

where W represents units of work, K is a constant, and P represents the average force required to produce rupture.

Thus Professor Richards's proof (*Text Book of Ore Dressing*, p. 167) is essentially as follows:

The number of planes of fracture of area one necessary to divide a cube (Fig. 6) of edge one along " n " planes parallel to a face of the cube is $n - 1$, and to divide the unit cube into n^3 smaller cubes of equal size requires fracture along $3(n - 1)$ planes of area one. If the work done to produce fracture along one plane of area one is B , then the work to divide the cube of edge one into n^3 smaller cubes of edge $\frac{1}{n}$ will be $3B(n - 1)$. Here the error creeps in. Professor Richards says further: "Applying this to any cube where D is the diameter of the original cube and d the diameter of the smaller resulting cubes in linear units, n becomes $\frac{D}{d}$. In making one cut through this cube, the area of fracture would be D^2 and our formula now becomes, $3BD^2\left(\frac{D}{d} - 1\right)$." [In the original notation A takes the place of B in the formulæ.]

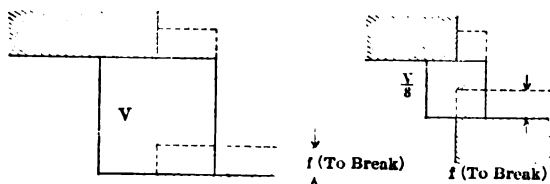


FIG. 7.

This can be true only if "force" and "work done" are identical. While it is true that the work done in producing fractures aggregating D^2 in area will be $3BD^2\left(\frac{D}{d} - 1\right)$ if the work is done separately on D/d cubes of edge one, it is not true that the work to produce a fracture of area D^2 in a cube of edge D will be $3BD^2\left(\frac{D}{d} - 1\right)$. The original assumption that B equals the work to produce a fracture of area one from a cube of edge one is true only if $B = \frac{e^2 AL}{2E}$ (assuming the rock perfectly elastic). In the particular case assumed, where the edge of the cube is taken as one, $B = \frac{e^2(1)^3}{2E} = \frac{e^2}{2E}$ and the volume relation is lost sight of; but when the edge of the cube is assumed to be D , the work to produce fracture along a plane of area D^2 is $\frac{e^2 D^3}{2E}$, and the total work required to reduce the cube of

edge D to $(D/d)^3$ cubes of edge d is $\frac{3e^2}{2E}D^3\left(\frac{D}{d} - 1\right)$, or the work is proportional to the volumes of the original and resulting cubes.

Gates recognizes the distinction between "work done" and "force required to do the work" and starts out with the statement:²

$$\text{Energy} = S'F'f$$

when applied to the theoretical cases illustrated in Fig. 7, where S' is the average resistance to shear per square inch, F' is the area of fracture for one break parallel to a face in a cube of volume V , $F'/4$ is the area of fracture for one break in a cube of volume $V/8$, and f is the distance moved through by the crushing faces to produce fracture. Gates admits that within the elastic limit of the substances, f is equal to a constant times the thickness (or diameter) of the body and hence that work to compress varies as the volume of the body, but he says further, when the forces are applied until rupture occurs:

"To break the molecular bond between adjacent particles would require the same movement regardless of the thickness of the piece."

"... it will not be hard to see that the distance through which the offset faces must move in either case must be the same and not proportional to the thickness of the piece."

If Gates intends to say that the forces applied by a crushing machine are such as to produce shearing stresses of the kind he represents, he is clearly wrong. If, on the other hand, the case is one of compression between two crushing faces, and we follow his statements through to their logical extreme, we will find that a deformation which is within the elastic limit, when a cube of rock of one thickness is compressed, is greater than the thickness of some other cube. It will follow, then, that with a movement of the crushing faces equal to the thickness of the smaller piece we will admittedly cause rupture of the smaller piece, while with the same movement the deformation of the larger piece will be within the elastic limit and no rupture will occur. To cite a specific instance, let us assume two cubes of magnesian limestone, the larger 8 in. on an edge and the smaller 0.0025 in. on an edge. Trautwine (*Engineer's Pocket Book*, 18th ed., p. 923) cites the result of a test by Capt. James B. Eads showing that a column of magnesian limestone 8 in. high and 2 in. in diameter shortened 0.0025 in. under pressure and recovered when relieved. If, then, we subject both of the above cubes to a crushing force which shall act through a distance of 0.0025 in., the small piece will be crushed, the large piece will not be ruptured, and the fallacy of Gates's argument will be made apparent.

² *Engineering and Mining Journal*, vol. xcv, No. 21, p. 1040 (May 24, 1913).

If we examine the two proofs just analyzed from another standpoint, starting with the fundamental equations

$$f = \frac{PL}{AE}$$

and

$$W = \frac{Pf}{2} = \frac{P^2L}{2AE}$$

if P and E are constant

$$W = \frac{KL}{A} \quad (K = \text{Constant} = P^2/2E)$$

or for a cube

$$W = \frac{KD}{D^2} = \frac{K}{D}$$

and the work done in producing a given deformation within the elastic limit is proportional to the reciprocal of the diameter of the particle deformed, which is the conclusion reached by Gates and Professor Richards.

But in no crushing machine in actual operation in the mills is the force exerted the same on pieces of all sizes. Hence the assumption that P is a constant is erroneous, and the conclusion drawn is likewise erroneous.

Before proceeding to a consideration of Del Mar's argument in support of Rittinger's law, an understanding of Stadler's method of application of Kick's law is necessary. In his paper *Grading Analyses and Their Application*, Stadler says:

"The volumes of the particles decrease from grade to grade at the same ratio as the number of particles, constituting in their total the volume of the unity, increases, and the product of the volumes into the number of the particles of that grade is, therefore, constant for each grade. As in conformity to the above law, the amount of energy absorbed is proportional to the volume of the body to be crushed, it follows again also that the total energy required for reducing the weight of the unit is constant for each grade.

"The ordinal numbers of any arithmetical progression given to these grades represent consequently the relative values of the energy which has to be spent upon producing this respective grade from the initial unit, or the *mechanical value* of the grade.

"For obtaining the *mechanical value of mixed sands*, we need only to multiply the percentages of the gradings by the number of the energy units of the respective grade and add the products. This possibility of having the gradings of pulps condensed and expressed in one representative figure proves to be of great value.

"The *useful work done per unit* by any crushing machine is determined by the difference between the mechanical values of the samples, taken at the inlet and the discharge of the machine, and for obtaining the *total work done* this difference has to be multiplied by the tonnage dealt with.

"The *relative mechanical efficiency* is the value obtained by dividing the total work done by the unit of energy (for instance, HP.):

Relative mech. efficiency =

$$\frac{\text{Tonnage} \times \text{Work done per unit in E. U.}''}{\text{Unit of Energy (HP.)}}$$

The use of the ordinal numbers or E. U. is illustrated in subsequent tables quoted from Del Mar's article.

Del Mar attacks the problem by means of the "deadly parallel." Taking grading analyses showing the results of three crushing tests, he computes the relative mechanical efficiencies according to the method of volumes (Stadler's method) and to the method of areas exposed by crushing. In applying this latter method Del Mar assumes the relative energy unit for each grade as the reciprocal of the average size of particle in the grade. The calculations, taken from Del Mar's article,³ follow:

CASE I

TABLE I.—Screen Analyses of Mill Material

Mesh	Mill No. 1		Mill No. 2	
	Mill feed %	Discharge %	Mill feed %	Discharge %
On 20.....	3.1	.....	15.1	3.5
On 40.....	15.5	3.2	35.6	21.2
On 60.....	15.6	4.5	10.4	14.1
On 80.....	14.6	10.5	11.1	17.9
On 100.....	9.6	15.8	6.4	11.2
On 120.....	2.4	2.4	0.7	1.6
Through 120.....	39.2	63.6	20.7	30.5

TABLE II.—Efficiency of Mill No. 1

Mesh	Reciprocal of average size	Feed %	Relative surface in feed	Discharge %	Relative surface in discharge
+20	26.5	3.1	82	.....	.....
+40	41.4	15.5	641	3.2	132
+60	83.6	15.6	1,304	4.5	376
+80	138	14.6	2,015	10.5	1,449
+100	163	9.6	1,564	15.8	2,575
+120	204	2.4	489	2.4	489
-120	253	39.2	9,917	63.6	16,090
Units of work in feed			16,012	Units of work in disch.....	21,111
Units of work in feed					16,012
Difference, units of work done					5,100

³ *Engineering and Mining Journal*, vol. xciv, No. 24, p. 1129 (Dec. 14, 1912).

TABLE III.—*Efficiency of Mill No. 2*

Mesh	Reciprocal of average size	Feed %	Relative surface in feed	Discharge %	Relative surface in discharge
+20	26.5	15.1	400	3.5	92
+40	41.4	35.6	1,473	21.2	877
+60	83.6	10.4	919	14.1	1,178
+80	138	11.1	1,532	17.9	2,470
+100	163	6.4	1,043	11.2	1,825
+120	204	0.7	143	1.6	326
-120	253	20.7	5,237	30.5	7,716
Units of work in feed			10,747	Units of work in disch.	
Units of work in feed					14,484
Difference units of work done					3,737

"Mill No. 1 has done 5100 units of reduction with an output of $2\frac{1}{2}$ tons per hp. or $5100 \times 2\frac{1}{2} = 12,750$ units of reduction work, while mill No. 2 has done 3737 units of reduction with an output of three tons per horsepower or 11,211 units of reduction."

This shows an excess efficiency of mill No. 1 over mill No. 2 of 12.7 per cent.

TABLE IV.—*E. U. of Mill No. 1*

Mesh	E. U. average size	Feed %	E. U. feed	Discharge %	E. U. discharge
+20	14.2	3.1	44.0	.....	.....
+40	16.2	15.5	251.1	3.2	51.8
+60	19.2	15.6	299.6	4.5	86.4
+80	21.0	14.6	306.6	10.5	220.5
+100	22.0	9.6	211.2	15.8	347.6
+120	22.8	2.4	54.7	2.4	54.7
-120	24.0	39.2	940.0	63.6	1526.4
Totals.....	.....	.....	2108.0	.....	2287.4

TABLE V.—*E. U. of Mill No. 2*

Mesh	E. U. average size	Feed %	E. U. feed	Discharge %	E. U. discharge
+20	14.2	15.1	214.4	3.5	49.7
+40	16.2	35.6	576.7	21.2	342.4
+60	19.2	10.4	199.6	14.1	270.7
+80	21.0	11.1	233.1	17.9	375.9
+100	22.0	6.4	140.8	11.2	246.4
+120	22.8	0.7	15.9	1.6	36.4
-120	24.0	20.7	496.8	30.5	732.0
Totals.....			1877.3		2053.5

"The first example, that of the two regrinding machines using the volume method, is worked out in Tables IV and V. For mill No. 1, this difference is 179 E. U. As the work done was $2\frac{1}{2}$ tons per hp., this multiplied by $2\frac{1}{2}$ will equal 447 E. U. For mill No. 2, the difference is 177.2. As the work done was three tons per horsepower, this multiplied by three equals 531 E. U. The work done by mill No. 2 is therefore 18% more than that done by mill No. 1, a direct contradiction of the relative efficiencies obtained by the reduction-in-diameter method."

CASE II

TABLE VI.—*Comparison of Single and Five-stamp Units*

Nissen stamp				5-stamp unit		
Mesh	Discharge %	Recip- rocal	Mechanical value	Discharge %	Recip- rocal	Mechanical value
+40	8.56	41.4	354	5.19	41.4	214
+60	13.92	83.6	1,163	13.75	83.6	1,149
+80	19.73	138.0	2,722	18.23	138.0	2,515
+100	3.40	163.0	554	3.21	163.0	523
+200	6.39	235.2	1,502	8.45	252.2	1,987
-200	43.39	400	17,356	48.82	400	19,528
Totals.....			23,651			25,916

"The single unit is a Nissen stamp of 1659 lb., $7\frac{1}{2}$ -in. drop at 100 per minute crushing $5\frac{1}{2}$ tons per stamp per day through a 40-mesh screen. The 5-stamp unit is a fast crushing design, 1250 lb., $7\frac{1}{2}$ -in. drop, 100 per minute, crushing 2.25 tons per stamp per day."

"The Nissen stamp has done 23,651 units of reduction with an output of 5½ tons and an estimated expenditure of 4.44 hp. or

$$\frac{23,651 \times 5\frac{1}{2}}{4.44} = 29,200 \text{ units of reduction}$$

while the 5-stamp mill has an output of 2.25 tons with 3.36 estimated hp., or

$$\frac{25,916 \times 2\frac{1}{4}}{3.36} = 17,300 \text{ units of reduction}$$

The mechanical efficiencies are then as 1:0.59 in favor of the Nissen stamp. The compiler of the figures stated that the power consumption was 50% less for the Nissen stamp. The above figures more than bear this out."

TABLE VII.—*Comparison of Single and Five-stamp Units*

Nissen stamp			5-stamp mill		
Mesh	E. U. average size	Discharge %	E. U. discharge	Discharge %	E. U. discharge
+40	16.2	8.56	138.6	5.19	84.0
+60	19.2	13.92	267.2	12.75	264.0
+80	21.0	19.73	414.3	18.23	382.8
+100	22.0	3.4	74.8	3.21	70.6
+200	23.7	6.39	151.5	8.45	200.2
-200	26.0	43.39	1128.4	48.82	1269.3
Totals.....			2174.8		2270.9

"Table VII shows the case of the Nissen stamps working in competition with the 5-stamp unit battery. The Nissen stamp has crushed 5½ tons with an estimated horsepower of 4.44 or

$$\frac{2175 \times 5\frac{1}{2}}{4.44} = 26.94$$

while the 5 stamp unit has crushed 2¼ tons with 3.36 hp. or

$$\frac{2271 \times 2\frac{1}{4}}{3.36} = 15.2$$

The two mills then have done work in the ratio of 1:0.56, nearly the exact ratio found by the previous calculation, using the reduction by diameter.

"Having considered the case of crushing from an impartial standpoint, it has been found that in two cases* under review the results are nearly identical, while in one case they are the reverse. In the case where the volume method shows the rearmush-ing mill No. 2 to have done better work than No. 1, the actual fact is that mill No. 1 does better work as shown by the reduction-of-diameter method."

The last statement is due to an error by Del Mar in the use of the term "relative energy" as defined by Stadler. The difference in E. U. as

* One case omitted.

developed by Del Mar (179 and 177.2 respectively) represents relative energy units per unit of weight, in this case the ton. The total relative work in each case is, then, the product of the relative work per unit of weight multiplied by the number of units of weight, or 13,425 and 13,215 respectively. This shows the relative work done in mill No. 1 greater than that in mill No. 2, as in Del Mar's method of calculation. The relative mechanical efficiencies obtained by the two methods are contradictory, as Del Mar remarks.

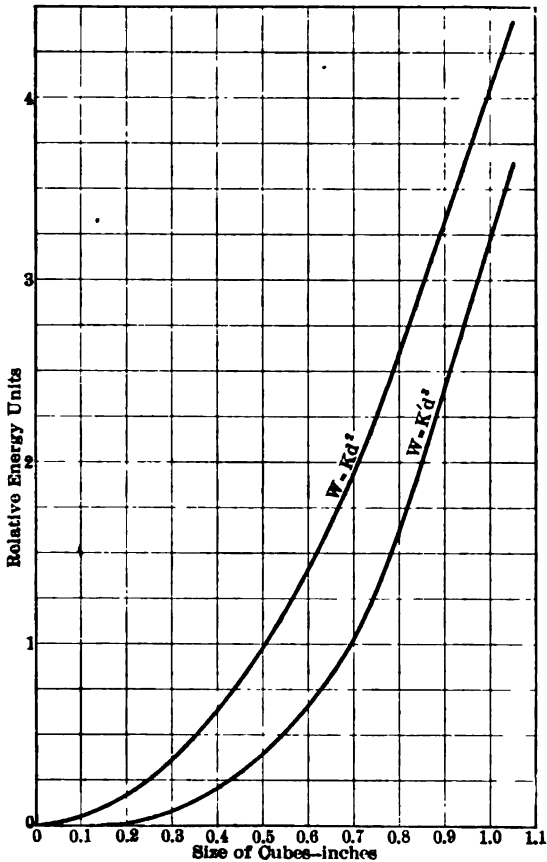


FIG. 8.

Part of the confusion that exists on this subject is due to the close agreement in the values of work over a certain range of the calculations under both methods. The reason for this apparent agreement is to be found in the graphs representing the two formulæ. The formula for work proportional to area of fracture is $W = KD^2$, which plotted gives a parabola. The formula for work proportional to volume is $W = K'D^3$, the graph of which is a cubical parabola.

In order to show the close agreement between these curves throughout a considerable range the ultimate unit stress per square inch to produce rupture in a highly elastic rock may be taken as 10,000 lb., and the deformation per inch of length from Eads's figure before cited as $1/3200$ in. The volume formula then becomes

$$W = 3.13 D^3$$

In order to bring the formula for work as advanced by Gates into as close agreement with this formula as possible it is assumed that in the case cited by Eads rupture would have taken place with a very slightly greater deformation than he gives, say 0.0004 in. per inch. The formula then becomes

$$W = 4D^3$$

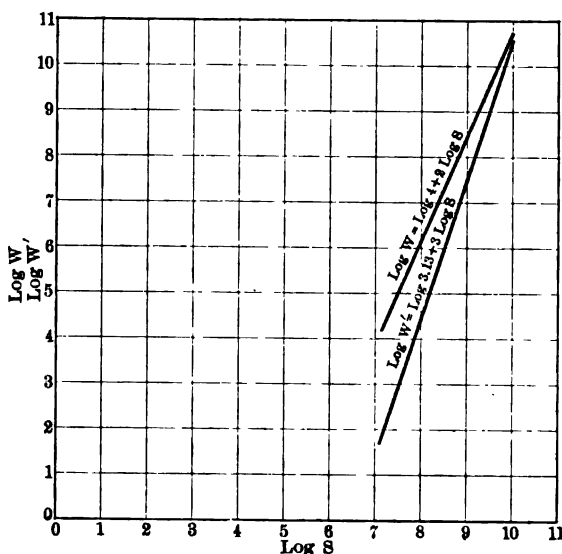


FIG. 9.

The graphs of these equations are shown in Fig. 8. They are closely parallel throughout a considerable range, showing the apparent agreement mentioned. The values near the origin of co-ordinates, where the agreement of the curves is least, are difficult to show in direct plotting. Fig. 9 represents the same equations plotted logarithmically. Here the divergence in the small sizes is very marked. That this is not wholly a mathematical divergence is apparent from the following quotation from Richards's *Text Book of Ore Dressing*, p. 170:

"Von Reytt has shown by a very exhaustive series of tests that the ratio of work done to increase the surface is fairly constant with coarser sizes, but that with fine sizes the increase of surface is much more rapid than the increase of work required to produce it."

In other words, the formula $W = KD^2$ gives high results in the fine sizes, as indicated by the upper curve, Fig. 9. If we look again at the tables given by Del Mar we see that in his second case, where the two methods agreed closely, there was but a small difference in the amount of very fine material in the two analyses given, while in his Case I there is a large difference and one of the percentages is very high. This aids the apparent agreement between the two methods of calculation in Case II and brings out the true divergence in Case I.

Summary

The work done in producing a given deformation of any body, within the elastic limit of the substance, varies as the volume of the body deformed.

For a highly elastic substance this principle may be extended beyond the elastic limit by the assumption that the force-deformation curve beyond the elastic limit is closely represented by a continuation of the straight line which represents the behavior of the body within the elastic limit.

For rock, which is almost perfectly elastic, this assumption is correct within the limits of experimental error.

The work of crushing rock is proportional to the volumes of the particles crushed, and to the volumes of the resulting particles.

Attempts to prove the work of crushing proportional to the reduction in diameter err in one of the following ways:

- (1) By neglecting the distance quantity in the work formula.
- (2) By assuming that particles in a crushing machine are acted upon in such a way as to produce simple shearing stresses.
- (3) By assuming that the force exerted is a constant.
- (4) By confusing "force" and "work."

The difference in the results obtained according to the two assumptions is small throughout a considerable range of sizes.

The difference is marked in the fine sizes, where the greatest amount of power is wasted.

In his original paper on this subject Stadler used 1 in. as the diameter of his unit grade and a volume reduction ratio of one-half for determining the other grades. He emphasized the fact that the method of calculation is independent of the screens used, the important matter to determine being the average diameter of grain in any grade. Then, by the formula $N = -10 \log S$, where N is the E. U. number for the grade and S is the average diameter, N may be determined. Unless, however, the screen apertures in the testing sieves used vary according to the ratio cube root of two, the values of N from Stadler's formulæ will not be whole numbers. This would be a trivial objection, since the slide rule is a part of the equip-

ment of all mills sufficiently up to date for screen analysis, if it were not for the fact that within the last year there has appeared in this country a set of testing sieves whose apertures vary according to the ratio square root of two, and which start from the U. S. standard 200-mesh sieve, 0.0029 in. clear aperture. This makes the coarsest screen of the series 1.050 in. clear aperture. Hence for this series of sieves the E. U. numbers of the different grades based on 1 in. as a unit will be all improper fractions, while with 1.050 in. taken as a unit the E. U. numbers are all whole numbers, and calculation with them is greatly simplified.

This difference in reduction ratio and unit aperture changes some of the formulæ originally stated by Stadler, and for the convenience of those who like to know the "why" of what they are doing and have not the time always to sit down and figure it out, the following proof, in general form, of the modified formulæ is appended. If we let

- P = the number of pieces produced from the unit at any size,
 S = sides of cubes (= mesh apertures),
 V = volumes of cubes (or weights),
 F = area of fracture with reference to unit,
 R = ratio of increase in volume of the particles from one grade to the next,
 N = Ordinal or Energy Number (E. U.) of grades,
 U = Length of edge of unit cube,

the following relations are easily developed:

$$P = U^3/S^3 \quad (1)$$

$$P = U^3/V \quad (2)$$

$$S = \sqrt[3]{V} \quad (3)$$

$$F = 3U^3/S \quad (4)$$

for F for any small cube broken from the unit equals $3S^2$ equals $3(U/n)^2$. And $P = n^3$. $S = U/n$. Hence $F \text{ total} = 3PS^2 = 3n^3U^2/n^2 = 3nU^2 = 3U^3/S$.

$$S = 3U^3/F \quad (\text{from 4}) \quad (5)$$

$$P = U^3/S^3 \quad (\text{from 1})$$

$$S^3 = 27U^3/F^3 \quad (\text{from 5})$$

Then $P = F^3/27U^6 \quad (6)$

$$V = U^3/P \quad (\text{from 2}) \quad (7)$$

$$S = \sqrt[3]{V} \quad (\text{from 3})$$

$$= \sqrt[3]{U^3/P} \quad (\text{from 7})$$

$$= U/\sqrt[3]{P} \quad (8)$$

$$V = S^3 \quad (9)$$

$$V = U^3/P \quad (\text{from 7})$$

$$P = F^3/27U^6 \quad (\text{from 6})$$

$$\text{Therefore } V = 27U^3/F^3 \dots \dots \dots : (10)$$

$$F = 3U^2/S \quad (\text{from 4})$$

$$= 3U^2/\sqrt[3]{V} \quad (\text{from 3}) \dots \dots \dots (11)$$

$$F = 3U^2/(\sqrt[3]{U^2/P}) \quad (\text{from 7 and 11})$$

$$= 3\sqrt[3]{PU^2} \dots \dots \dots (12)$$

$1/R = r$ = Volume reduction ratio.

For one reduction $V_1 = rV_0$

For the second reduction, $V_2 = rV_1 = r^2V_0$

For N reductions, $V_N = r^NV_0$

But $V_0/V_N = P$

$$\text{Therefore } P = 1/r^N = R^N \dots \dots \dots (13)$$

$$S = U/\sqrt[3]{P} \quad (\text{from 8})$$

$$= U/\sqrt[3]{R^N} \quad (\text{from 13}) \dots \dots \dots (14)$$

$$V = U^3/P \quad (\text{from 7})$$

$$= U^3/R^N \quad (\text{from 13}) \dots \dots \dots (15)$$

$$F = 3\sqrt[3]{PU^2} \quad (\text{from 12})$$

$$= 3\sqrt[3]{R^N U^2} \quad (\text{from 13}) \dots \dots \dots (16)$$

$$P = R^N \quad (\text{from 13})$$

Taking logarithms of both sides:

$$\text{Log } P = N \text{ log } R$$

$$N = (\text{Log } P)/\text{Log } R \dots \dots \dots (17)$$

$$P = U^3/S^3 \quad (\text{from 1})$$

Taking logarithms of both sides:

$$\text{Log } P = \text{Log}(U^3/S^3)$$

$$= 3(\text{Log } U - \text{Log } S)$$

$$\text{Therefore } N = 3(\text{Log } U - \text{Log } S)/\text{Log } R \dots \dots \dots (18)$$

$$P = U^3/V \quad (\text{from 2})$$

Taking logarithms of both sides:

$$\text{Log } P = \text{Log } U^3 - \text{Log } V$$

$$\text{Therefore } N = (3 \text{ Log } U - \text{Log } V)/\text{Log } R \dots \dots \dots (19)$$

$$P = F^3/27U^6 \quad (\text{from 6})$$

Taking logarithms of both sides:

$$\text{Log } P = \text{Log}(F^3/27U^6)$$

$$= \text{Log } F^3 - \text{Log } U^6 - \text{Log } 3^3$$

$$= 3(\text{Log } F - 2 \text{ Log } U - \text{Log } 3)$$

$$\text{Therefore } N = 3(\text{Log } F - 2 \text{ Log } U - \text{Log } 3)/\text{Log } R \dots \dots (20)$$

Table of Formulæ for Determining Stadler's Constants

	P	S	V	F	N
P.....		U^2/S^2	U^2/V	$F^2/27U^2$	R^N
S.....	$U/\sqrt[3]{P}$		$\sqrt[3]{V}$	$3U^2/F$	$U/\sqrt[3]{R^N}$
V.....	U^2/P	S^2		$27U^2/F^2$	U^2/R^N
F.....	$3(\sqrt[3]{P})(U^2)$	$3U^2/S$	$3U^2/\sqrt[3]{V}$		$3\sqrt[3]{R^N U^2}$
N.....	$\frac{\text{Log } P}{\text{Log } R}$	$\frac{3(\text{Log } U - \text{Log } S)}{\text{Log } R}$	$\frac{3 \text{Log } U - \text{Log } V}{\text{Log } R}$	$\frac{3(\text{Log } F - 2 \text{Log } U - \text{Log } 3)}{\text{Log } R}$	

$$N = \frac{3 \text{Log } U - \text{Log } V}{\text{Log } R} \quad (\text{from 19})$$

Therefore

$N = \text{a function of } V$

But Work = Force $\times$ Distance

and Force varies as F

or Force = KF (where K is the average unit force to produce fracture).

Distance is a constant function of the diameter for any grade and is equal to a constant, C (determined by the modulus of elasticity of the material), times the diameter, or

Distance = CS

Therefore Work, to rupture one particle at any grade, = $KFCS$.

But there are P particles of any given grade in the unit.

Therefore W , to crush the unit volume (or weight) at any grade, = $PKFCS$.

But $P = \frac{U^2}{V}$ (from 2)

$F = \frac{3U^2}{S}$ (from 4)

Therefore $W = \frac{U^2 \times S \times 3U^2 \times KC}{VS} = \frac{3KCU^6}{V}$

That is, $W = \text{a function of } V$

But $N = \text{a function of } V$

Then $W = \text{a function of } N$.

Obviously, for sizes larger than U the value of N will be negative. In such a case the mechanical value of the pulp is the algebraic sum of the mechanical values of the individual grades.

The following table gives the values of N, P, V, S, and F for the Tyler standard screen scale sieves:

Constants for Tyler Standard Screen Scale Sieves

Apertures S		Volumes V (= S ³)		Area of fracture F (= 3U ² /S)		No. of pieces P (= U ³ /V)	Ordinal or energy number. N (= Log P/LogR)
Inches	Milli- meters	Cubic inches	Cubic millimeters	Square inches	Square millimeters	From unit	
1.050	26.67	1.1576	18,970	3.3075	2,133.8	1	0
0.742	18.85	0.40851	6,697.7	4.6804	3,019.1	2.8338	1
0.525	13.33	0.14470	2,368.6	6.6150	4,260.2	8.000	2
0.371	9.423	0.051063	836.7	9.3610	6,039.3	23.671	3
0.265	6.680	0.018192	298.09	31.205	8,519.2	63.635	4
0.185	4.699	0.0063316	103.76	18.773	12,111	182.83	5
0.131	3.327	0.0022481	36.826	26.511	17,105	514.94	6
0.093	2.362	0.00080434	13.178	37.343	24,093	1,439.2	7
0.065	1.651	0.00027462	4.5004	53.429	34,460	4,215.4	8
0.046	1.168	0.000097333	1.5934	75.497	48,723	11,893	9
0.0328	0.833	0.000035287	0.57803	105.88	68,317	32,806	10
0.0232	0.589	0.000012487	0.20434	149.71	96,618	92,704	11
0.0164	0.417	0.0000044108	0.072513	211.76	136,470	262,450	12
0.0116	0.295	0.0000015609	0.025672	299.39	192,910	741,630	13
0.0082	0.208	0.00000055176	0.0089988	423.53	273,600	2,099,600	14
0.0068	0.147	0.00000019511	0.0031766	598.77	387,140	5,933,100	15
0.0041	0.104	0.000000068919	0.0011238	847.06	547,300	16,797,000	16
0.0029	0.074	0.000000024389	0.00040522	1,197.5	769,040	47,484,000	17
0.0014	0.037	0.000000003045	0.00004989	2,396.0	1,545,500	380,320,000	19

a Assumed.

The Metallurgy of Zinc

A discussion at a joint meeting of the New York Section of the American Electrochemical Society and the American Institute of Mining Engineers, Nov. 20, 1913.

Chairman Lawrence Addicks:—Our program this evening represents an attempt to set before you the present situation and outlook in the metallurgy of zinc.

It is a time-honored custom to throw bricks at the zinc man. The accusation is that he has borrowed a lime kiln and a gas retort and part of a sulphuric acid plant, hitched them together, and spent the last 50 years in regarding with holy veneration the reactions which take place in that retort. The copper man, who thinks of zinc as something with which copper is adulterated to make brass, and the iron man, who regards it as a sort of paint for corrugated sheets, and the lead man, whose opinion as to zinc is not fit for publication, have long felt that, when two or three of the minor details of their respective metallurgies were put in order, they would take a few days and fix up zinc on a modern basis. But somehow there still seem to be some unsolved problems at home, and while we are waiting it seems only fair that the case for the defense should be adequately presented. There is probably no man in this country to-day better able to do this than Mr. George C. Stone, of the New Jersey Zinc Co., on whom I have pleasure in calling to talk to us on "Progress in the Metallurgy of Zinc."

George C. Stone:—It is frequently stated that there has been no change in the metallurgy of zinc since the first Belgian furnaces were built in the early part of the last century. It is true there have been no such spectacular and radical changes as were worked in the metallurgy of copper and iron by the introduction of converters; but, in the essentials, I believe the progress in zinc metallurgy has been as great as in that of the other common metals.

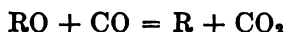
The main reason that there have not been revolutionary changes is that the chemistry of zinc differs radically from that of the other metals and these differences control the type of apparatus that can be used. The differences are:

1. The temperature at which zinc is reduced by carbon is much above the volatilizing point of the metal and it is therefore always produced as a vapor.

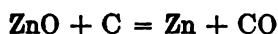
2. To obtain a merchantable product the vapor must be condensed at a temperature well above the melting point of the metal. More than this, the temperature necessary to condense zinc depends on the concentration

of its vapor and is lower the more dilute the vapor. When the mixture of zinc vapor and gases enters the condenser it is rich in zinc, and the condensation temperature must therefore be high in order to prevent sudden solidification and the production of blue powder. As the vapor leaves the condenser it is very dilute and unless the condenser temperature is much lower there will be a loss of zinc. This means that the temperature of the condenser must be close to the boiling point of zinc (920°) at the end nearest to the retort and very much lower at the opposite end.

3. The reaction by which most metals are obtained commercially is



With all the common metals but zinc this reaction is only reversed when there is a considerable change in temperature or a very large increase in the concentration of CO_2 in the atmosphere. Neither of these is quite true of zinc. For any given temperature the equilibrium between CO_2 and the zinc vapor determines the amount of reaction. That is, the reduction of zinc proceeds until there is a certain ratio of CO_2 to zinc in the atmosphere, and then stops. A decrease in the CO_2 causes the reaction to start again in the same direction and an increase causes it to start in the opposite direction. The lower the temperature the less CO_2 is required to reverse the reaction. In order to effect complete reduction this equilibrium must be continually destroyed by the presence of an excess of carbon, and the equation must be either



or



These three essential facts limit the possible apparatus for the production of zinc in several ways. The reduction must take place in a closed chamber to prevent the loss of volatilized zinc. As the reoxidation is proportional to the total CO_2 present and not to its concentration, and as the difficulty of proper condensation increases very rapidly with dilution of the zinc vapor, the volume of gas going off with the zinc must be kept as small as possible. This means that the gases from the heating fuel must not come in contact with the charge, or, in other words, the heating must be external. As the mixture of ore and coal forming the charge is a poor conductor of heat, the size of the chamber containing it must be small in at least one direction or the heating will be too slow. The charge must, at all stages, contain a large excess of carbon to at once reduce all CO_2 formed. The condensers should be as close to the charge as possible and as small as will do the work, in order to make it possible to maintain the proper heat gradient in them. The condensers must be kept within proper limits of temperature, diminishing toward the exit.

The first spelter furnaces built filled these conditions and it is difficult to conceive of any other type that will do so.

It is commonly stated that the spelter furnace is very extravagant in heat. This I venture to question. Any furnace in which the issuing gases heat the incoming charge and thereby economize fuel is out of the question, for reasons already given. It is therefore necessary to introduce cold charge in the furnace and heat it there. The heat used for this purpose is certainly not wasted. The heat escaping to the stack is not a large proportion of the total in a properly designed regenerative furnace supplied with gas of good quality, especially if waste-heat boilers are placed between the furnace and the stack. The main unavoidable loss of heat is by radiation. The end walls of the furnace are usually made very thick and the radiation from them is not great. The radiation from the roof is much greater and is often excessive, as the roofs are usually thin. A great part of this loss can be prevented by covering the roof with a thick layer of porous material, such as well-burned boiler ashes. The main radiation is from the front of the furnace, and this is necessarily so as the front must be made very thin in order to keep the retorts hot to the ends, otherwise there would be a considerable amount of unworked charge left in the front. But is this large radiation all loss? Considered only in relation to the heat required for reduction, yes; but considered in relation to the heat required for the entire operation, no. This heat is only sufficient, and not always sufficient, to keep the condensers up to the proper temperature, and it should therefore not be considered as lost, as heat from some other source would have to be supplied to the condensers if this were not available. This radiated heat regularly and automatically keeps the condensers at a suitably graded temperature, which would be difficult to do if they were heated in any other manner.

Remembering the limits imposed by the chemical properties of zinc, let us examine the progress that has been made.

Forty or fifty years ago the typical Belgian furnace contained from 50 to 90 retorts of about 0.8 cu. ft. capacity each. At the present time the furnaces used in the natural gas field contain from 500 to 700 retorts of about 1.4 ft. each, an increase in capacity of about 1,300 per cent. Furnaces containing 1,008 retorts are in operation doing satisfactory work; this is an increase of about 2,400 per cent. in size and capacity. The increase in capacity of the spelter furnaces is therefore about the same as that of the modern coke furnace making pig iron over the old charcoal furnace.

Mere increase in size, however, does not amount to much unless accompanied by increased efficiency. In this respect the zinc furnaces show well. In the iron furnaces there has been no improvement in the proportion of metal recovered, the old furnaces having given almost theo-

retical results. With zinc the improvement has been very marked. In 1844 at the Vieille Montagne works the recovery was about 62 per cent., and even as late as 1880 75 per cent. was considered good work. To-day 87 per cent. is only fair, and many works can show runs of long periods averaging 90 per cent. and over.

The fuel consumption has been decreased largely, mainly by the adoption of regenerative gas-firing. Comparing only furnaces using the same kind of coal—where the hand-fired furnaces 25 years ago required 3, 3.5 and even 4 tons of coal per ton of ore, well-equipped gas furnaces using the same coal and working the same class of ore now take only 1.5 to 1.75 tons.

Labor has also been largely reduced. The old Belgian furnaces required five days' labor per charge, two men working 24 hr. continuously, and an extra helper on the day shift only. As these furnaces worked only about a ton of ore they required five days' labor per ton. At present all 24-hr. work is done away with, and not over 1.5 days' labor is required per ton.

In 1844, 15 to 20 days was the usual life of a retort. Now good retorts made in hydraulic presses last from 30 to 40 days, and at that more are replaced because they are filled up than because they leak.

Regarding the future, I believe progress will continue to be made, but rather on the lines of improvement in the present processes than by the adoption of radically different ones.

Three main classes of processes have been proposed: the wet, the electrolytic, and the electrothermic.

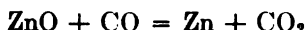
So far none of the wet processes has proved successful. One main reason for this is the difficulty of dissolving the zinc. The most abundant ore of zinc is blende, which always contains some and usually a large proportion of iron. When the ore is roasted the zinc and iron combine to form zinc ferrite, which is practically insoluble in either acids or alkalies under economic conditions. To decompose a ferrite requires a large excess of acid and long boiling. The purification of the solution is also expensive and troublesome. Many inventors have proposed to precipitate the zinc from the solution as carbonate, convert this to oxide by heating, and sell the products as a pigment. This is not possible on a commercial scale, as small amounts of basic salts are always formed and these render the oxide of zinc made of no value as a pigment; it will not mix properly with oil and has very little covering power. The processes that start by treating the sulphides with chlorine do not appear promising on economic or technical grounds.

Electrolytic zinc of excellent quality has been made by one firm for several years, but they have never increased the original plant. It is generally believed that this plant is only possible in connection with other operations carried on by them. As a general proposition, electrolytic processes have the same disadvantages as the wet, in the difficulty of

making and purifying the solutions, and the added one of large power requirements. The minimum power necessary to precipitate zinc electrolytically is known, and a simple calculation will show that the amount required will cost more than coal smelting at any location in this country where zinc ore occurs in quantity.

In this country at least ores and coal do not occur near each other; and water power is seldom available. Therefore power is expensive at the mine, and the freight rates on ore to points where power is cheap are high. The result is the same whether the ore is treated at the mines or brought to the power; cheap ore and power are not available at the same point. This very seriously limits the economical possibilities of electric smelting. The lowest estimate I have seen of the power requirements is 1,200 kw.hr. per ton of ore, which means that power must not cost over 0.5 c. per kilowatt-hour if it is to compete with the present smelting processes.

So far the yields of merchantable spelter reported as made in electric furnaces have been very low. This is not at all surprising and is, I believe, due partly to the difficulty of properly regulating the temperature of the condensers, but more to the reoxidation of the zinc by the CO_2 in the gas forming an excessive quantity of flue dust or blue powder, which has to be reworked. That there is likely to be a much greater reoxidation in most of the electric furnaces that have been described in print than in the ordinary retort is obvious. The reactions by which zinc is reduced are the same whether the heating is by electricity or fuel:



and



In the body of the charge the two reactions take place at the same time and the excess C destroys the equilibrium and there is no reversal. At the surface of the charge only the first takes place and the CO_2 formed there goes forward and oxidizes the part of the zinc in the condenser. In the long, narrow zinc retort packed full of charge the ratio of the exposed surface to the total volume of the charge is very small and only a small amount of CO_2 is formed. In most of the electric furnaces of which I have seen drawings the ratio of surface to volume of charge is much greater and more CO_2 will go to the condenser, which accounts for the greater proportion of zinc reoxidized.

In many of the electric furnaces the operation is continuous; that is, ore and fuel are charged either continuously or at short intervals. This charge of ore and coal always contains entangled air and moisture and frequently CO_2 ; these are rapidly driven off and dilute the outgoing gases, making the condensation more difficult and causing a reoxidation of the zinc. It has been proposed to preheat the charge, which would

decrease these troubles, but only partly, as the temperature necessary to drive off combined water and CO_2 completely and in a reasonable time is as high as the reduction temperature of ZnO .

This is confirmed by the fact that, other things being equal, a tightly charged retort will give a smaller proportion of blue powder than one loosely charged and therefore having a greater ratio of surface to volume; also that with the Silesian practice, where the free surface is very large per unit of charge, a larger proportion of blue powder is made than with the Belgian practice, where it is much smaller.

To be economical electric furnaces must be in much larger units than zinc retorts, and the condensers also must be larger. It is obvious that the difficulty of keeping all parts of a condenser within the narrow limits of temperature allowable will increase very rapidly as its size increases. Increased size of furnace, which is necessary for low power consumption, therefore means an increased difficulty in condensation; and, even with the small furnaces so far built, this difficulty has been one of the most serious that has been met.

The present types of furnaces can be much improved. Fuel can be saved by better design and proportions of regenerators, better arrangement of the parts, and decreasing radiation losses by more thorough lagging of the parts of the furnaces from which radiation is purely wasteful. A determination of the best size and shape of retort and condenser for different ores, and the choice of such as suit the particular ore to be worked, instead of using one size and arrangement for all, will give improved results in recovery and output. A careful study and application of the principles on which ores should be mixed offers a wide field for improvement.

There have been patented a number of furnaces for the production of zinc. Several of these are on the general lines of the present furnaces, and many of them show probabilities of being advantageous. Many others are shaft furnaces, some heated by coal and some electrically. Nearly all of these have the peculiarity of requiring the zinc vapor to go in one direction and the gases in another, which is obviously impossible of accomplishment. The coal-fired furnaces of this type have the additional disadvantage of producing a large volume of gas, which would much increase the amount of blue powder made and the difficulty of condensation.

In the old days metallurgy was purely empirical and progress was slow in all lines. Iron and steel were the first to be taken up by trained men, and the results they obtained were startling and revolutionary. Copper and lead followed next, with equally beneficial results. Zinc was about the last to employ trained metallurgists, but they have taken hold of it at last, and I have sufficient confidence in them to believe they will continue to improve on the good work they have already done.

The Chairman:—The Lord has been very good to us in the matter of zinc deposits and the fact that it is so easy to prepare a concentrate running 50 or 60 per cent. of zinc has made it difficult to pay for metallurgical refinements, and zinc in complex ores has been until lately nothing but an undesirable impurity. The small clay retort does not lend itself to the formation of liquid by-products, such as lead and copper matte; and the electric furnace with its nearly perfect control of atmosphere and internal generation of heat demands consideration. The electric furnace also opens the way for continuous smelting.

I was reading the other day a reprint of a letter dated July 4, 1585, from one Frosse, smelting copper ores in Wales, to the man supplying him with ore, one sentence of which read: "We have found a way to smelt 24 cwts. of ore every day with one furnace, the Lord be thanked, and if we may have ore enough from your side we may, with God's help, melt with two furnaces in forty weeks 560 tons of ore, desiring you from henceforward to send such ores as you have with as much speed as may be, not caring what ore it is."

This is more or less the message of the electric zinc furnace, which Mr. W. R. Ingalls, who has made a special study of the question, will now present.

W. R. Ingalls:—In the case of those ores from which a recovery of lead and silver also is expected to be made, we should make our comparison (of cost) with the cost of the total process, including both the recovery of the zinc and the recovery of the lead and the silver that goes along with it. In the matter of energy, which in the process of fire smelting is used in the form of coal, and in the electrical process in the form of electric current, our feet are probably on firmer ground, at least as to what we may reasonably hope for, than with respect to most other items of cost. In the smelting of a thousand kilograms of ordinary zinc ore, of about 40 per cent. zinc contained, we estimate that from 900 to 1,000 calories of heat are necessary, which is equivalent to 1,047 to 1,163 kw-hr. of electric energy. While it is doubtful if any such result has yet been actually realized by any one, the claim of ability to smelt a ton of ore for 1,200 kw-hr. is plausible with respect to certain kinds of ores, although even then it is necessary to estimate a high furnace efficiency. However, it is known that electric furnaces do give high efficiency. Several years ago I expressed the opinion, in a paper that I gave before the Kendall Mining Institute, that 1,200 kw-hr. for 2,000 lb. of ore would be a sufficiently brilliant realization. I have no reason to change that opinion. In citing that figure, I mean of course to make a broad generalization; if the electric smelting process is conducted as a two-stage process, the preheater naturally would be operated by coal, and in the delivery of partly reduced and hot ore to the electric furnace the electric power required in the latter naturally would be reduced. I think, indeed,

that that is the proper direction in which to work—*i.e.*, to use the cheaper coal energy wherever it can be used, and confine the more costly electric energy to the work for which it is especially needed.

Accepting my estimate of 1,200 kw-hr. as a generalization, and a possible realization, we can readily see that under any conditions of power supply that we know of in this country the power cost in reducing a ton of ore will be a good deal more than the coal cost. In the items of administration, general expense, and yard labor we may expect the same costs in the one process as in the other. The cost of roasting will probably be about the same in both processes, though we may admit some economy in favor of the electric smelting process because the ore for that process may not have to be desulphurized so completely, and we may want not to desulphurize it so completely as in the ordinary process. In the matter of reduction, cost is undoubtedly in favor of the electric process. We cannot, in the electric furnace, use the same proportion that we do in the ordinary furnace, even if we should want to. I think it would be better if we could.

We may study the question of retorts and the question of electrodes. My friend Mr. Lyon, in a paper he read before the Electrochemical Society last autumn, criticized an editorial in the *Engineering and Mining Journal* on this subject. It was said that at the present time we do not know which would be the more costly. He did not refer by name to me, but I accept full responsibility for the statement which was made then, and I will stick to it. Mr. Lyon argued at considerable length about electrodes, that they would be very much cheaper than retorts of the ordinary furnace. He may be right. I say only that at the present time we do not know, and in the only extensive work in electric smelting that we know of, at least that I know of, the work in Scandinavia, the only place where electric smelting has been conducted month in and month out and in the treatment of many hundreds of tons of ore, the cost of electrodes has been very much higher than the cost of retorts in the ordinary processes.

The matter of labor cost in the two processes is also uncertain. At first sight, one would think that in running an electric furnace of 3 or 5 tons capacity the labor cost would be much lower than in our old-fashioned furnaces, in which we deal with miserable little retorts; that may be so; I am not sure of it; we know that in the case of Trolhätta the labor cost has been very much more than in the ordinary fire smelting.

The cost of repairs and renewals is another item as to which, at the present time, we have no knowledge.

In the matter of capital charges, I think it is not unlikely that the electric plant will have a little advantage, especially if it be not charged with the cost of electric installation, which of course would be improper,

because we have reckoned that already in considering the matter of energy.

Summarizing, if the unit quantities of materials used at Trohätta are multiplied by American processes, or such processes as exist in our regions west of the Rocky mountains, the country where, especially, we think of electric smelting as being of probable advantage, the cost of application of that process would be absolutely prohibitive; that is something that we know quite definitely.

This whole subject of electric smelting is still very much in its infancy. It is going to be a good many years yet before it is developed into a commercial process, I think; and it is not unlikely that ways around many of these difficulties, in matters of cost, may be found, so that we shall in one way or another be able to see some advantage in it. I hope we shall; I think it is a subject that is very well worth working on, but at the present about all that we can say is that we don't know.

The Chairman:—Fractional distillation does not give a perfectly sharp separation between zinc, cadmium, and lead, and as these three elements are commonly associated in zinc ores, the spelter of commerce does not rank in purity with several of the other metals. Outside of the spelter made from such unusual ores as those of New Jersey and West Virginia, there is no zinc on the market which does not carry considerable lead—a very undesirable impurity in brass. Electrolytic refining of a crude spelter or deposition from a leach liquor has long been discussed, but it is only within the last year or so that large zinc producers have taken an active interest in the investigation. The experience gained in the use of addition agents in the electrolysis of other metals in the last ten years is of great assistance; and further, the ease with which zinc electrolytes can be purified by the addition of zinc dust simplifies the problem. The great question is how to pay for it, in the absence of any insistent demand for practically pure spelter and of any considerable recovery of silver or gold.

We were promised by Dr. Frank, the American representative of Siemens & Halske, a paper for this evening by Mr. Victor Engelhardt, Chief Engineer of that company, who has done a great deal of original work along these lines. This paper has not materialized. I am informed that it has been written, but whether it has been withdrawn or is delayed in the mails, I have been unable to ascertain in the absence of Dr. Frank, who sailed for Europe last week.

Dr. Joseph W. Richards has very kindly consented to handle the subject of Electrolytic Zinc on very short notice, and has not had time to prepare a formal paper. As there are a number of gentlemen present who are familiar with the work at present being done in this country, I hope they will amplify Dr. Richards's talk in the discussion.

J. W. Richards:—I will endeavor to put before you shortly the

elements of the topic which our friend Dr. Engelhardt would have given you. The electrolytic precipitation of zinc from solutions may be found in the literature best set forth in Dr. Guenther's book, the German edition of which I have here, and I will refer to the contents of this book to show you the field:

First: Processes using soluble anodes.

Second: Those which use insoluble anodes.

Under the head of those processes which use soluble anodes, he speaks of the refining of zinc by electrolysis, and there are five different processes scheduled, so that the attempt to electrolytically refine zinc has attracted considerable attention.

Under the head of the use of insoluble anodes there are some 30 processes catalogued, some of which have been used on a large scale commercially, but none of which is to be regarded, as yet, as permanently established.

Dr. Engelhardt, a little less than a year ago, read a paper before the German Metallurgical Society, on the topic of Recent Processes in the Electrolytic Production of Zinc. I have an abstract of this paper here, which was published last January; I will briefly quote his remarks, and add some observations of my own.

He says first of all that the amount of zinc made in the world is about 800,000 metric tons a year, and thinks that if electrolytic zinc is made it must be sold in competition with ordinary zinc, since there is only a limited demand for very pure high-price zinc. The mere refining of commercial zinc, analogous to copper refining, is considered by Dr. Engelhardt to be economically absurd. It may be economically impossible at the present time, and under most conditions, but I do not think it is an economical absurdity. The idea of refining zinc electrolytically, as copper is refined, has less hope of commercial success than that of copper. First, there is a smaller margin of difference in price between the crude zinc and the pure zinc than there is in copper; secondly, the refining is more difficult and more costly. The idea, however, is not an absurdity.

It is about a little over 20 years ago that I conducted some experiments on the electrolytic refining of zinc, using for anodes the hard zinc which is made in the galvanizer's pot. There is a plentiful supply of that material, and the electrolytic refining of it is something that is well worthy of consideration. In those experiments I used permanent cathodes of heavy sheet zinc, greased them over with wax and later with glycerine, so I could strip the zinc from them. I have run zinc plates for as much as six days, and have obtained heavy, good deposits of zinc with a current density of 45 amperes per square foot. The melting down of the zinc is apt to give a large loss, but it can be done economically, as Dr. Engelhardt says, with a loss of only .3 per cent. of the weight of the zinc. The zinc

strips from the cathodes nicely, and the solution can be kept free of iron by aerating it rapidly, then taking the solution out of the tank and filtering it; it can thus be kept free of iron and the solution thus purified without removing any of the zinc. Calculations showed that at that time the process could have been operated at a small margin of profit; the margin of profit, however, was not sufficient to justify the putting up of a plant to do it commercially.

At the present time, however, something analogous to the electric refining of zinc is being operated, in the *cold galvanizing*, or electroplating with zinc anodes.

Dr. Engelhardt takes up a second topic, using anodes with the precious metals, and again notes that these have not been successful commercially.

Dr. C. F. Chandler was requested by the Chairman to speak on the subject under discussion, and did so in his usual witty manner.

W. McA. Johnson.—I was interested to notice that Mr. Ingalls says 1,200 kw-hr. is possible for a ton of zinc ore, and that is the best that he could do. I have always set my mind that 1,200 kw-hr. is the worst that I could do. In this point, I see some chance for the redemption of Mr. Ingalls's soul from his agnostic attitude on electric zinc smelting. We have run around 950 to 1,000 or 1,100 kw-hr. per ton of ore. The furnace is rather small, of 45 kw. capacity, and it is easy to see that if the larger furnaces were used the kilowatt-hours on the roasted ore would be considerably less, for it is a principle of electro-metallurgy that the efficiency of the furnace increases as size of furnace increases.

There is not much doubt that in a good-sized furnace, say 250 kw., we can expect an efficiency of 65 per cent. At efficiency of 65 per cent., I estimate, with an average ore running 30 per cent. zinc, making about 25 per cent. slag, that we will run at 750 kw-hr. per ton of roasted ore.

With regard to the amount of electrode consumption, we measure our electric consumption at Hartford on the basis of a thousand kilowatt-hours. Figures give an average of 6.5 to 7 lb. of carbon consumed per 1,000 kw-hr. This is rather an "incidental" consumption. Electrode carbons cost here 4c. to 5c. per pound in large quantities; in Europe much less. The electrode cost in electric zinc-furnace plants, running under proper conditions and not with an abundance of oxidizing gases, would therefore be from 25c. to 50c. per ton of ore, or 50 per cent. of the cost of the retort and condensers in retorting process.

The success of electric zinc smelting, as I look at it, in this country at least, hinges entirely upon our ability to smelt complex sulphides. There is a quantity of zinc ore of this kind in the West. Our practice at Hartford is opposed to the retort process. Whereas they make a dry residue, we make a slag. Our slag is just as fusible as possible. The amount of these ores is large.

In making a slag we have found that our losses in copper and in lead

were a great deal lower than the losses in the lead furnace or in the copper furnaces. The analysis of 16.9 tons of slag made in the year June, 1912, to June, 1913, is as follows:

Zn.....	5.25	per cent.
Cu.....	0.065	per cent.
Pb.....	0.05	per cent.
Ag.....	0.5	oz. per short ton.
Au.....	0.01	oz. per short ton.

Before the slag gets down to smelting bath of slag, most of the zinc is taken out. Consequently, when we have 2 per cent. of copper in a charge, we are really smelting 4 per cent. ore, for the reason that half of the charge passes as gas to the condenser. I have here an analysis of a run of ten days, in which some 6 or 7 tons of ore were treated. This analysis is as follows:

Zn.....	0.65	per cent.
Cu.....	0.12	per cent.
Pb.....	0.00	per cent.
Ag.....	0.15	oz. per short ton.
Au.....	0.01	oz. per short ton.

Therefore, due attention must be paid to the by-product recoveries in estimating what electric smelting of zinc will do commercially.

Mr. Ingalls spoke about the necessity of making condensible gases; this point is the essence of good zinc smelting. We have condensed from complex sulphide ores considerable spelter in the last year and a half or two years. We rarely condense less than 70 per cent. of gas. One of our men made the following aphorism: "Give me a good gas and I can condense zinc in a flower-pot."

Our practical rule is that the amount of iron or copper should be divided by a certain factor, and this should represent the amount of sulphur in the ore. I suppose as far as practice goes we will roast to 5 per cent. sulphur. I had some experience at roasting zinc ores down to 0.5 per cent. sulphur, and there is no doubt that the cost of plant, the cost of operation and the quality of gas made for the acid plant are going to be greatly affected by the fact that we will roast zinc ores to 5 per cent. sulphur, which is what we need it in the electric smelting of zinc ores. Here the commercial advantage is all in favor of our process. We are now building a furnace which is an assembling of all the different parts of the process developed in the last four years. We are now, to the best of our ability, putting all our work into one form. This furnace will have a capacity of 3 tons of ore, and possibly more, before we get through. We will have an exact record of all the details of its operation, and we will be glad to show any of you gentlemen who care to come to Hartford the working of this furnace. Zinc comes from Missouri and we must "show" people.

E. G. Spilsbury:—I do not know that I can add much of value to what has been said this evening, excepting that I think probably one of the great difficulties being now encountered in properly condensing the volatilized zinc in the continuous electric furnace is due to a material difference in the methods of reduction in this furnace as compared with that as used in the retort distillation process. In the retort furnace, where the charge is mixed with from 40 to 50 per cent. of ground coal, there are clearly two distinct periods of operation. During the first period—lasting several hours—the charge is gradually being heated and the volatile hydrocarbons contained in the coal are gradually driven off, at a temperature considerably below the volatilization temperature of the zinc, and practically all of these highly oxidizing gases are driven off before the reduction of the zinc begins. The result of this is that when this point is reached the metallic gases evolved are not contaminated and diluted with oxidizing agents, and, therefore, the condensation is very thorough. The reduction in the retort, while slower than in the electric furnace, is more complete, owing to the fact that the fine coal being thoroughly mixed with the particles of ore these latter are exposed on all sides to the highly reducing action of the nascent CO gas, which is a very different reducing agent from CO gas not produced in actual contact with the ore.

I remember some years ago, when I was in the zinc business, making some experiments along that line, in which we charged the ore in an ordinary retort without the addition of coal; the retorts so charged were fitted with an opening in the back end by which pure carbonic oxide—produced from charcoal and heated to the temperature of the furnace—was passed through the retort containing the zinc ore. The reactions were different to what we expected and the distillation of the zinc vapor began almost immediately after the introduction of the gas, and continued with considerable rapidity for about 2 hr., after which the reaction became less and less and finally usually stopped when about 40 per cent. of the zinc contained in the charge had been extracted. The continuance of the experiment after this only resulted in the fusing of the charge, which was probably the reason why the CO gases could not react any longer on the zinc contained in the ore.

Now in the continuous electric furnace the difficulties of condensation are probably caused mainly by the final distillation of the coal taking place at the same time as the distillation of the zinc and thereby impoverishing the combined gases going over into the condenser to the extent of hindering the condensation of the zinc vapor into metallic globules rather than into the fine spongy condition known as blue powder. This will probably be obviated by making the interior surface of the condenser of a fire clay mixture, as rough as possible, so that the travel of the [heavier metallic gases will be retarded and their con-

densation assisted, while the lighter gases, having a much lower condensation temperature, will travel unimpeded to the exit at the end of the prolonge. The higher percentage of condensation obtained in the later form of construction of the Johnson furnace is due, I think, very considerably to this form of condenser.

It should also be borne in mind, I think, that in the operation of the continuous zinc furnace, where the aim is to recover not only zinc, but also the other metals of value in the ore in the form of matte or bullion, considerably more sulphur is allowed to remain in the charge than would be permissible for retort distillation purposes. The mere carbon reduction of this sulphur-bearing ore naturally results in the formation of a highly oxidizing gaseous agent, unless care is taken to provide in the charge such metallic constituents as will have greater affinity for the sulphur evolved than zinc has. The failure to furnish this agent in the De Laval furnace is the main reason why they produce nothing but blue powder and oxide. On the contrary, the method of producing metallic iron sponge in the preheater of the Johnson furnace accounts also for the larger production of metallic spelter in the condenser.

In reply to a question Mr. Johnson said:

"Speaking about the amount of blue powder, I suppose in the last year and a half our condensation factor (that is, the weight of zinc condensed to spelter divided by weight of the zinc delivered to the condenser) will average about 75 per cent. We make from 1 to 5 per cent. of blue powder, and 15 to 20 per cent. of flue dust. One must discriminate in his mind clearly between flue dust and blue powder. Flue dust will have a lot of zinc in it as shot (0.25 in. in diameter) and considerable lime and coal dust and fine ore carried over mechanically. Blue powder will have little of these. One of the forms of blue powder is what we denominate as "gamma" blue powder. This is "chemical" blue powder which cannot be turned by any means into spelter. It can be discriminated from the ordinary blue powder made by the action of CO_2 by the analysis, or by looking at it under a microscope. This blue powder is caused by the action of sulphur, either as CS_2 or as sulphur emanating from the matte, on the zinc gas. This all has been described in our Canadian patent issued February, 1913."

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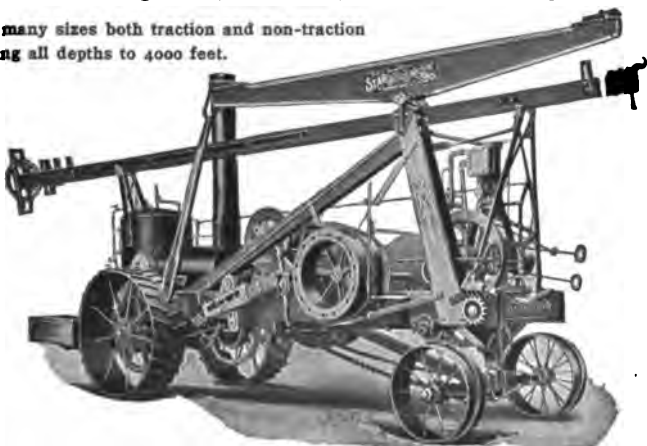
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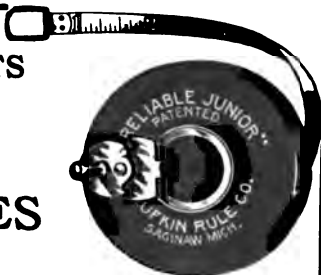
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FEBRUARY, 1914



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REPORT OF COMMITTEE ON INCREASE OF MEMBERSHIP, 1913

Since the organization of this Committee in May, its personnel has been increased by the appointment of Mr. F. D. Power in Australia, Mr. Charles Rhodes in New Zealand, Mr. T. Inouye in Japan, and Mr. M. B. Yung and Mr. Cho Yang in China. Mr. Corning, the first Chairman of the Committee, has been in Bolivia, so that the Institute is strongly represented in foreign countries. The first work to which we addressed ourselves was the inviting of all properly qualified graduates of the principal mining schools in this country and abroad to join the Institute. Letters, signed by some prominent professor or alumnus of the school, were sent to the graduates in mining of Columbia, Harvard, Sheffield Scientific, Michigan, Case School of Applied Science, Washington, Colorado, Wyoming, Toronto, Pennsylvania State, Stevens, Rensselaer, and several other mining schools as well as to recent graduates of the Universities of Berlin and Madrid. It is difficult to ascertain the exact number of new members that have been thus secured, as in many cases the source of an application cannot be determined, but enough have been traced to indicate satisfactory results for the effort expended. Through the assistance of Mr. E. W. Parker, similar invitations have been extended to all the members of the staff of the Bureau of Mines and the U. S. Geological Survey, also to all the State mine inspectors, with satisfactory results. At the suggestion of Mr. Rand, certain members of the Committee have undertaken to make a record of the principal contributors to some of the leading technical journals, ascertain whether they are qualified for membership, and, if so, invite them to join. Some returns have been secured from this source also.

More recently our efforts have been directed at enlisting more general participation of the membership at large in the work of the Committee, and at the suggestion of Mr. Stoughton, and with the permission of the Board of Directors, this Committee has been allowed the privilege of using an announcement page in the front of the *Bulletin* each month, following the example of the American Society of Mechanical Engineers. This step is too recent to indicate what results have been

attained. Mr. Stoughton has also written to the Chairman of each Local Section requesting the co-operation of the Section in securing new members, and has also, in welcoming each new member to the Institute, suggested that he secure other members. This would seem a peculiarly useful method of procedure, and indeed, as an *ex officio* member of the Committee, Mr. Stoughton has given freely both assistance and advice.

The most effective work has been done by the President of the Institute, Mr. Charles F. Rand, who in December sent out a letter urging each member to secure another. As a result some 300 applications for membership have been received, making the total for 1913 (to December 31) 608 applications for membership. Of these, 450 have been elected, and 433 have already accepted election. The applications received during the year thus are within 100 of the total for the three preceding years. Perhaps the most gratifying feature of this is the character of the new members, a large number of whom are graduates of technical schools with five or ten years' practical experience. The grade of membership is therefore, in the opinion of the Committee, being elevated, rather than lowered by the activities of this Committee. In the light of the year's experience, we have the following recommendations to make:

1. That the Committee be reorganized so as to permit the appointment of Vice-Chairmen resident in the principal mining districts and larger cities of this country, who will have charge of the work of the Committee in their territory, and that there should be 10 Vice-Chairmen, each resident in the territory of Local Sections or important mining districts.

2. The appointment of new members so that we shall have at least one member of the Committee in each State.

3. That the work during 1914 be devoted, in addition to continuing present activities, toward securing the active participation of the membership at large.

A. E. BORIE, *Chairman*.

T. T. READ, *Secretary*.

PROPOSAL FOR MEMBERSHIP

[illegible]

[illegible]

*Present position*_____

Signature.

Dated _____ *191*

EXTRACTS FROM THE CONSTITUTION.

ARTICLE II.—MEMBERS.

SEC. 2. The following classes of persons shall be eligible for membership in the Institute, namely : as Members, all professional mining engineers, geologists, metallurgists, or chemists, and all persons actively engaged in mining and metallurgical engineering, geology, or chemistry ; as Associates, all persons desirous of being connected with the Institute who in the opinion of the Board of Directors are suitable.

Every candidate for election as a Member, Associate, or Junior Member must be proposed for election by at least three Members or Associates, must be approved by the Committee on Membership, as prescribed in the By-Laws, and must be elected by the Board of Directors.

BULLETIN OF THE AMERICAN INSTITUTE OF MINING ENGINEERS

No. 86

FEBRUARY

1914

Published Monthly by the American Institute of Mining Engineers at 212-218 York St., York Pa., H. A. WISOTSKY, Publication Manager. Editorial Office, 29 West 39th St., New York, N. Y., BRADLEY STOURGHTON, Editor, F. O. PIERCE, Asst. Editor. Cable address, "Aime," Western Union Telegraph Code. Subscription (including postage), \$10 per annum; to members of the Institute, public libraries, educational institutions and technical societies, \$5 per annum. Single copies (including postage), \$1 each; to members of the Institute, public libraries, etc., 50 cents each.

Entered as Second Class matter January 28, 1914, at the Post Office at
York, Pennsylvania, under the Act of March 3, 1879.

INTERNATIONAL ENGINEERING CONGRESS

This Congress will be held under the auspices of five National Engineering Societies, of which the Institute is one. The sessions will be held in 11 sections and the proceedings will be published in 10 volumes of 500 pages each, of which Volume 8 will contain the papers and proceedings on Mining Engineering and Metallurgy. The membership fee of \$5 will entitle the holder to the volume of General Proceedings and Index, and, in addition thereto, any other single volume chosen. Other volumes may be subscribed for according to a sliding scale depending upon the number of volumes taken. The Institute will have a meeting in San Francisco during 1915, and it is desirable for our members to join the International Engineering Congress at an early date in order that their support of the enterprise may be given in its early stages, when it is most needed.

Library Hours.—The Library Board, at the suggestion of several members, has voted to keep the library open until 10 o'clock in the evening. In order to give a fair test of the increased use, the extra hour will be added until August 1. Members all over the world are again reminded of the valuable service which the library is able to give through the mails, the details of which are given on p. xvi.

BOARD OF DIRECTORS

Meeting of Jan. 23, 1914.—The President reported the appointment of Arthur S. Dwight and E. Gybbon Spilsbury as tellers to canvass the votes for the Annual Election of Directors.

The President reported the appointment of the Committee on Precious and Base Metals, reorganized in accordance with the list on page xlv.

The Treasurer was authorized to invest the sum of approximately \$1,000, accruing from the sale of Life Memberships during the past year, by the purchase of one gold bond of the Interborough Rapid Transit Co., due 1966, at 5 per cent.

The By-Laws of the San Francisco Local Section were approved.

The recommendation of the Lord Kelvin Memorial Fund Committee that the balance of the fund unexpended be applied to the establishment of a Kelvin Gold Medal was approved.

Forty-two members who had paid up all arrears of dues were reinstated.

The sum of \$100 was appropriated to the Columbia Local Section.

The price of each of the three Volumes of *Transactions* of the year 1913 was established as \$5 in paper and \$6 in half-morocco.

Forty-three Members, One Associate and four Junior Members were elected to membership in their respective classes.

Correction.—The remarks on electric zinc smelting in the last *Bulletin*, quoted from a talk given by W. R. Ingalls, before a joint meeting of the New York Sections of the American Electrochemical Society and the American Institute of Mining Engineers, were merely the stenographer's notes of a portion of Mr. Ingalls's address, and are more or less erroneous. Mr. Ingalls did not revise them and did not know that this publication was contemplated. This correction is made at the request of Mr. Ingalls.

Copies of Volume X of the Transactions Wanted.—Owing to the scarcity of Volume X, the Secretary of the Institute has been authorized to offer the sum of \$10 each for these volumes bound in half-morocco, or \$9 each bound in paper. In the event of not being able to secure a sufficient number of these volumes at these prices, the volume will be republished, after which copies will not be bought by the Institute.

PERSONAL

(Members are urged to send in for this column any notes of interest concerning themselves or their fellow-members.)

Members and guests who registered at Institute headquarters during January:

A. Neustaedter, Jersey City, N. J.	William Jones, Kent, England.
A. I. Sweetser, Boston, Mass.	Percy E. Barbour, Candor, N. C.
Algernon Del Mar, Los Angeles, Cal.	Herbert S. Kohlberg, El Paso, Texas.
W. B. Cogswell, Syracuse, N. Y.	I. N. Knapp, Ardmore, Pa.
R. E. Chambers, New Glasgow, N. S.	

George A. Camphius, mining engineer, has opened an office in the Mills Building, El Paso, Texas, and will make a specialty of engineering and mine management.

Edward A. Loring has been appointed Manager of the Phoenix mine, Cornwall, England.

Edward Manion has been appointed General Manager of Wasp No. 2, at Flatiron, S. D.

J. A. Rule has been made Assistant Superintendent of the International smelter at Tooele, Utah.

Stanley C. Sears, consulting mining engineer and metallurgist, has opened an office at 705 Walker Bank Building, Salt Lake City, Utah.

H. A. Guess has been made Consulting Engineer for the American Smelting & Refining Co., with headquarters at New York.

B. W. Vallat has resigned as Superintendent of the Newport Iron Mines, Mich.

Dr. Richard Moldenke has resigned as Secretary of the American Foundrymen's Association. He will continue to edit the *Proceedings*.

William S. Mann is superintending the construction and installation of an all-sliming cyanide mill for the Socorro Gold & Silver Mines, Ltd., at Valle de Angeles, Honduras, Central America.

Richard S. McCaffery, formerly Professor of Mining and Metallurgy at the University of Idaho and Chairman of the Spokane Section of the American Institute of Mining Engineers, has been appointed Professor of Metallurgy in the University of Wisconsin.

POSITIONS VACANT

(Under this heading will be published notes sent to the Secretary of the Institute by members or other persons.)

Large steel castings company in East has opening for a sales engineer. Technical knowledge of the manufacture and application of steel castings essential. Exceptional opportunity with high salary for right man. No. 8.

Position open as assistant superintendent at a steel plant. Practical experience in the manufacture of crucible and open-hearth steel and heat treatment of steel and alloy steels required. This position offers an excellent future. No. 9.

ENGINEERS AVAILABLE

(Under this heading will be published notes sent to the Secretary of the Institute by members or other persons.)

Member, technical graduate, age 35, with 10 years' experience in mining, cyaniding, and copper lixiviation in Arizona, Colorado, Nevada, Mexico and Central America, desires a position, preferably in Spanish American country. No. 50.

Member, technical graduate, age 28, with six years' experience in mine surveying, sampling, and timbering, and in mine supervision in Colorado and Arizona, is open for engagement as mine engineer, assistant superintendent, or superintendent. No. 51.

Technical graduate, age 33, married, wishes position. Five years' mining experience, for last 18 months chief engineer of large copper company in Mexico; also seven years' experience as machinist. No. 52.

Young man with eight years' experience as draftsman, surveyor, and engineer desires position as engineer, preferably in United States. No. 53.

Member, technical graduate, age 48, with 18 years' experience in mining and milling work in Washington, Arizona, Colorado, and Utah, desires position as superintendent or manager of metal mine. No. 54.

Member, age 35, with experience as assayer, surveyor, mine and mill foreman, superintendent, and manager in Arizona, California, Nevada, Mexico, and Korea, open for engagement as manager or superintendent. No. 55.

Member, technical graduate, age 32, with varied experience in exploration and examination work and placer mining in United States, Canada, and Alaska, open for engagement as manager of mining or exploration work. No. 56.

Physician, 30 years old, single, with experience as assayer and chemist with mining companies, is desirous of obtaining a position in Latin America. No. 57.

Member, graduate mining engineer, with exceptional experience as mine superintendent, seeks engagement. No. 58.

Member, technical graduate, age 32, with seven years' experience as engineer and superintendent of gold, silver and pyrites mines in Mexico and United States, desires position as manager or superintendent. No. 59.

Member, mining and metallurgical engineer of 19 years' practical experience in examination, development, design, construction, and management of mining and milling properties. An executive with a splendid record of efficient management. No. 60.

Mining engineer and metallurgist open for engagement after Mar. 1, as mill superintendent, superintendent of mines, or constructing engineer. Technically educated, with 14 years' experience in United States and Spanish America in mining, concentration, amalgamation, cyaniding, constructing. Just completed a large up-to-date all-sliding cyanide mill in Central America. Speaks Spanish fluently. No. 61.

Member, graduate mining engineer, 33 years old, with experience in underground engineering, mining geology, construction, and as mine superintendent, assayer and metallurgist, mill superintendent, and general superintendent, now open for employment as general superintendent or manager of a metal mine. Has had valuable experience in sulphuric acid leaching of copper ores. Minimum salary, \$4,000 per year. No. 62.

IRON AND STEEL COMMITTEE

ALBERT SAUVEUR, *Chairman*A. A. STEVENSON, *Vice-Chairman*HERBERT M. BOSTON, *Secretary*, Abbot Bldg., Cambridge, Mass.

Guilliaem Aertsen,	Robert W. Hunt,	E. Gybbon Spilsbury,
John Birkinbine,	J. E. Johnson, Jr.,	J. S. Unger,
William H. Blauvelt,	William Kelly,	Felix A. Vogel,
Charles A. Buck,	Charles Kirchhoff,	Leonard Waldo,
James Gayley,	Richard Moldenke,	William R. Walker,
Henry D. Hibbard,	Joseph W. Richards,	William R. Webster,
Henry M. Howe,	C. F. W. Rys,	Frederick W. Wood.

Manuscripts of the following papers on iron and steel for the February meeting have been received and accepted:

Albert Sauveur, Notes on Heating and Cooling Curves of Professor Carpenter's Electrolytic Iron.

H. M. Howe and A. G. Levy, Notes on the Plastic Deformation of Steel during Overstrain.

J. E. Johnson, Jr., The Influence on the Quality of Cast Iron Exerted by Oxygen, Nitrogen, and some Other Elements.

C. D. Young, O. D. A. Pease and C. H. Strand, Treatment of Steel Castings.

R. W. Hunt, The American Steel Rail Situation.

Sir Robert Hadfield, Manganese-Steel Rails.

Sir Robert Hadfield, Research with Regard to the Magnetic and Non-Magnetic Conditions of Manganese Steel.

Sir Robert Hadfield, Sound Ingots.

Robert M. Keeney, Pig Steel from Ore in the Electric Furnace.

W. S. Potter, Manganese Steel, with Especial Reference to the Relation of Physical Properties to Microstructure and Critical Ranges.

S. G. Valentine, Blast-Furnace Operation with the Turbo-Blower.

A. N. Diehl, Data Pertaining to Gas Cleaning at the Duquesne Blast Furnaces.

The following papers have been promised for the February meeting, but at this writing the manuscripts have not been received:

Albert Sauveur, Mayari Steel.

J. V. Emmons, The Surface Decarbonization of Tool Steel.

R. H. Rice, The Turbo-Blower.

The following subjects have been suggested for future papers and members of the Institute are invited to make suggestions to this Committee of other subjects to be added to the list:

The Electric Furnace for Steel Making.

The Electric Furnace for the Manufacture of Steel Castings.

The Generation of Steam by Waste Heat from Open-Hearth Furnaces.

Special Steels (including Cobalt Steel and Cupro-Nickel Steel).

Mayari Steel Rails.

Nodulizing of Ores for the Blast Furnace.

The Efficiency of Blast-Furnace Stoves.

Gas Engines of All Sizes, referring more particularly to gas engines used at steel works and actuated by blast-furnace gas or coke-oven gas or both. (There is a prospect for one paper on this subject for the February meeting, but we want more papers on the same subject.)

Steam Turbines and Turbine-Blowers, including the low-pressure turbines used on the exhaust from steam engines at blast furnaces and steel works. (Two papers on this subject have been promised for the February meeting, but more papers should be secured.)

Oxygen in Steel.

The Duplex Process of Steel Manufacture.

The Slagging Producer.

The Use of Pulverized Coal for Fuel.

HERBERT M. BOYLSTON, *Secretary*.

PENNSYLVANIA ANTHRACITE LOCAL SECTION

On Saturday evening, Jan. 31, 1914, about 40 members of the Institute met at the Hotel Sterling, Wilkes Barre, Pa., for the purpose of discussing plans for the formation of a local section in the Pennsylvania anthracite region. President Rand; Prof. Joseph W. Richards, of the Board of Directors; Dr. H. M. Chance, Chairman of the Committee on Coal and Coke, and Secretary Stoughton were among the guests present.

R. V. Norris acted as Master of Ceremonies, and the arrangements were all made in advance by a Committee under the leadership of CharlesENZIAN, to whom an enthusiastic vote of thanks was accorded at the dinner.

An address was made by President Rand, followed by Professor Richards, who outlined the procedure necessary for the formation of a Local Section. Addresses were then made by W. J. Richards, F. W. Chase, C. F. Huber, R. J. Foster, F. A. Hill, H. M. Chance, Bradley Stoughton, and others, after which a rising vote was taken, and it was unanimously decided to petition the Board of Directors for the establishment of the Pennsylvania Anthracite Local Section. More than the required number of members then signed the petition, and President Rand announced the appointment of a Committee to organize the Section and arrange for a meeting in accordance with their By-Laws, consisting of R. V. Norris, W. J. Richards, R. J. Foster, Edwin Ludlow, C. F. Huber, CharlesENZIAN, Douglas Bunting, F. A. Hill, and J. M. Humphrey.

BOSTON LOCAL SECTION

Executive Committee

ROBERT H. RICHARDS, *Chairman*

ALBERT SAUVEUR, *Vice-Chairman*

AUGUSTUS H. EUSTIS, *Secretary-Treasurer*, 131 State St., Boston, Mass.

TIMOTHY W. SPRAGUE

HENRY A. WENTWORTH

*Fifteenth Meeting**

The fifteenth meeting of the Boston Local Section was held at the Engineers' Club, Monday evening, Dec. 1, 1913. Fifty members were present.

* Received by the Secretary, Jan. 9, 1914.

Vice-Chairman Albert Sauveur presided at the dinner, after which he introduced the guest of the evening, Prof. J. W. Richards, who spoke on The Electro-Chemical Industries of Norway and Sweden.

Professor Richards stated that the subject was far too large to attempt to cover systematically. He pointed out the great natural advantages which Norway enjoys for power development, and stated that if all the power of Norway were developed there would be 5,000,000 h.p. without any artificial regulation, and with artificial regulation this power could be increased to 10,000,000 h.p. There is already in use about 900,000 h.p. The original cost of developing this power is only from \$25 to \$50 per horse power; the actual cost of the power per year to the consumer ranges from \$4 to \$8 in Norway, and from \$8 to \$12 in Sweden. The powers developed are being used to-day in various chemical industries.

Professor Richards described the nitric acid works in Telemarken. The first step in the process is to make nitric acid from the nitrogen of the air, and this acid is then combined with lime to make calcium nitrate, which is used as a fertilizer. In the southern part of Norway, at Christiansand, nitrate of soda is made by a similar process. Next in importance to the nitric acid industry is the cyanamide process, which is used in direct connection with the calcium carbide works at Odda; the product is also used as a fertilizer. There are also zinc and aluminum works, and copper and nickel refineries; also other electric zinc works near the Swedish Border, and at Trollhättan in Sweden.

The first pig-iron furnace was started in Norway, but has since been shut down; there are still in regular operation electric furnaces producing steel, and sending their products to Sheffield. One of these steel works makes a business of breaking up old ships, and melting down the steel for steel castings.

At the close of Professor Richards's talk, which was beautifully illustrated with colored lantern slides, there was some discussion by the members present, and all concurred very heartily in appreciation of Professor Richards's kindness in coming to Boston to lecture to the Society.

Sixteenth Meeting

The sixteenth meeting was held at the Harvard Club, Monday evening, Jan. 5, 1914, with 26 members present.

Chairman Robert H. Richards presided at the dinner, at the close of which he introduced as the speaker of the evening, Dr. Rossiter W. Raymond, who spoke on The Mineral Land Law of the United States, tracing the history of Federal legislation on this subject from the time when the nucleus of the public domain was established by the cession to the United States by certain of the original thirteen States of the Western lands belonging to them under royal grants. After describing the experiment of leasing mineral lands in the Mississippi valley, tried for 40 years, and abandoned by Congress in 1847, he sketched the manner in which, after the rediscovery of gold in California, the present system of United States mineral-land law grew up, first through the customs of the miners themselves, in the absence of any legislation, and then through a series of endeavors to legalize and regulate those customs.

In conclusion Doctor Raymond expressed the fear that the repeal of the mischievous features of the present mineral-land law might be

delayed or prevented by attempts to revolutionize the system of mineral-land patents altogether, and make the Federal government a perpetual landlord, leasing mineral lands. This proposition he generally deprecated.

AUGUSTUS F. EUSTIS, *Secretary*.

PUGET SOUND LOCAL SECTION

Executive Committee

JOSEPH DANIELS, *Chairman*

J. N. POTT, *Vice-Chairman*

I. F. LAUCKS, *Secretary-Treasurer*, 95 Yesler Way,
Seattle, Wash.

A. F. BLAIR

CHESTER F. LEE

A monthly meeting of the Puget Sound Local Section was held on Saturday, Dec. 13, with an attendance of about 25.

Dr. C. E. Weaver, of the University of Washington, who has made special study of the geology of this section with reference to oil resources, gave a very interesting and instructive talk on The Possibilities of Oil Development in the State of Washington. There was no other business before the section.

A meeting of the Section was held Jan. 17, at the Rathskeller, with about 25 present. No business was transacted, and the time was spent in the discussion of the topic, Metal Mining in the Cascade Mountains, Its Possibilities and Future, Messrs. Roberts, Weaver, Powell, Hill and Daniels speaking on the subject.

Topics for discussion at coming meetings of the Section are as follows:

February: Coal Mining in Washington. Speakers, Messrs. Hill, Evans, Pott, Butler, Slater, and Claghorn.

March: Metallurgy of Washington and Alaska Ores. Speakers, Messrs. Morse, McLeod, and Chase.

April: Coal Washing as applied to Washington Coals. Speakers, Messrs. Blair, Slater, Hill, and Butler.

I. F. LAUCKS, *Secretary*.

COLORADO LOCAL SECTION

Executive Committee

FRANK BULKLEY, *Chairman*

S. A. IONIDES, *Vice-Chairman*

C. LORIMER COLBURN, *Secretary-Treasurer*,
614 Ideal Building, Denver, Colo.

JAMES A. McCLAVE

DAVID G. MILLER

The annual meeting of the Colorado Local Section was held, following a luncheon, at the Adams Hotel, on Saturday, Jan. 17, 1914. The Chairman, William J. Cox, called the meeting to order and made a short

address covering the work of the Section. The Treasurer reported receipts for the year 1913 of \$48.25 and expenditures of \$33.95.

The following officers were elected unanimously:

FRANK BULKLEY, *Chairman*

S. A. IONIDES, *Vice-Chairman*

DAVID G. MILLER, JAMES M. MCCLAVE, *Directors*

C. LORIMER COLBURN, *Secretary-Treasurer*

A. A. Blow, R. D. George, Fred H. Bostwick, David W. Brunton, George W. Schneider, Thomas B. Stearns, and Charles J. Moore made short addresses.

A vote of thanks was extended to the retiring officers for their faithful attendance to duty and untiring efforts in building up the Section.

C. LORIMER COLBURN, *Secretary*.

SOUTHERN CALIFORNIA LOCAL SECTION

Executive Committee

THEODORE B. COMSTOCK, *Chairman*

SEELEY W. MUDD, *Vice-Chairman*

FREDERICK J. H. MERRILL, *Secretary-Treasurer*,
300 Germain Building, Los Angeles, Cal.

C. COLCOCK JONES

FRANK ROBBINS

A meeting of the Southern California Local Section was held at its headquarters on Jan. 15, 1914, 15 members and 3 guests being present.

The meeting was called to order by the Chairman, Dr. T. B. Comstock, who opened discussion on the announced subject, The Relation of Geology to Mining, with a description of some of his professional experiences in Mexico, Arizona, and Alaska.

S. W. Mudd spoke of the late S. F. Emmons, in connection with the geological survey of Leadville and of his influence in connection with the late Clarence King in guiding the work of the U. S. Geological Survey into channels of economic usefulness.

Frank Robbins spoke of the importance of geology to mining and related several humorous anecdotes connected with his personal experience. Further discussion on incidents of personal experience was contributed by Messrs. P. Wiseman, A. B. Carpenter, S. W. Mudd, E. A. Haggott, L. F. S. Holland, and F. J. H. Merrill.

The Chairman then summed up the communications of the evening and the meeting adjourned to social enjoyment.

F. J. H. MERRILL, *Secretary*.

EMMONS VOLUME ON ORE-DEPOSITS

A continuation of the "Posepny" Volume

Comprising papers descriptive of ore-deposits and discussions of their origin, edited, with an introduction, by Dr. S. F. Emmons. The volume contains also a Biographical Notice of Dr. Emmons by his associate and friend, Dr. George F. Becker, and a comprehensive Bibliographical Index of the Science of Ore-Deposits, prepared by Prof. John D. Irving, of the Sheffield Scientific School of Yale University. Dr. Emmons had finished his editorial work and written his Introduction before his lamented death in 1910; and the Volume contains his last words upon the subject to which he had given the work of his life, and on which he was justly regarded as the foremost authority.

Contents

- Genesis of Certain Ore-Deposits. By S. F. EMMONS.
 Structural Relations of Ore-Deposits. By S. F. EMMONS.
 Geological Distribution of the Useful Metals in the United States. By S. F. EMMONS. Discussion, by JOHN A. CHURCH, ARTHUR WINSLOW, S. F. EMMONS, and WILLIAM HAMILTON MERRITT.
 Torsional Theory of Joints. By GEORGE F. BECKER. Discussion, by H. M. HOWE, R. W. RAYMOND, C. R. BORD, and GEORGE F. BECKER.
 Allotropy of Gold. By HARRY LOUIS.
 Superficial Alteration of Ore-Deposits. By R. A. F. PENROSE, JR.
 Some Mines of Rosita and Silver Cliff, Colorado. By S. F. EMMONS.
 Genesis of Certain Auriferous Lodes. By JOHN R. DON. Discussion, by JOSEPH LE CONT, S. F. EMMONS, G. F. BECKER, ARTHUR WINSLOW, W. P. BLAKE, and J. R. DON.
 Influence of Country-Rock on Mineral Veins. By WALTER HARVEY WEED.
 Igneous Rocks and Circulating Waters as Factors in Ore-Deposition. By J. F. KEMP.
 Consideration of Igneous Rocks and Their Segregation or Differentiation as Related to the Occurrence of Ores. By J. E. SPURR. Discussion, by A. N. WINCHELL.
 Chemistry of Ore-Deposition. By WALTER P. JENNEY. Discussion, by JOHN A. CHURCH.
 Ore-Deposits near Igneous Contacts. By WALTER HARVEY WEED. Discussion, by W. L. AUSTIN.
 Ore-Deposition and Vein-Enrichment by Ascending Hot Waters. By WALTER HARVEY WEED.
 Basaltic Zones as Guides to Ore-Deposits in the Cripple Creek District, Colorado. By E. A. STEVENS.
 Geological Features of the Gold-Production of North America. By W. LINDGREN. Discussion, by W. G. MILLER and W. L. AUSTIN.
 Osmosis as a Factor in Ore-Formation. By HALBERT POWERS GILLETTE.
 Ore-Deposits of Sudbury, Ontario. By CHARLES W. DICKSON.
 Genesis of the Copper-Deposits of Clifton-Morenci, Arizona. By W. LINDGREN.
 Copper-Deposits at San Jose, Tamaulipas, Mexico. By J. F. KEMP.
 Magmatic Origin of Vein-Forming Waters in Southeastern Alaska. By A. C. SPENCER.
 Genetic Relations of the Western Nevada Ores. By J. E. SPURR.
 Are the Quartz Veins of Silver Peak, Nevada, the Result of Magmatic Segregation? By J. B. HASTINGS.
 Occurrence of Stibnite at Steamboat Springs, Nevada. By W. LINDGREN.
 Summary of Lake Superior Geology with Special Reference to Recent Studies of the Iron-Bearing Series. By C. K. LEITE.
 Geological Relations of the Scandinavian Iron-Ores. By H. SÖDERGREN.
 Formation and Enrichment of Ore-Bearing Veins. (With Supplementary Paper.) By GEORGE J. BANCROFT.
 Distribution of the Elements in Igneous Rocks. By H. S. WASHINGTON.
 Agency of Manganese in the Superficial Alteration and Secondary Enrichment of Gold-Deposits of the United States. By W. H. EMMONS.
 Cognate Papers.
 Bibliography of the Science of Ore-Deposits. By J. D. IRVING, H. D. SMITH, and H. G. FERGUSON.

The volume contains 1002 pages. Price, bound in cloth, \$5; in half-morocco, \$6. Both the Emmons and the Posepny Volumes on Ore-Deposits, bound in cloth, \$8; in half-morocco, \$10.

READY FOR DISTRIBUTION

LIBRARY

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

AMERICAN SOCIETY OF MECHANICAL ENGINEERS

AMERICAN INSTITUTE OF MINING ENGINEERS

UNITED ENGINEERING SOCIETY

WILLIAM P. CUTTER, Librarian

The Library of the above-named Societies is open from 9 A.M. to 9 P.M. on all week-days, except holidays, from September 1 to June 30, and from 9 A.M. to 6 P.M. during July and August. The Library contains about 55,000 volumes, including sets of technical periodicals and the publications of scientific and technical societies.

Members of the Institute, with few exceptions, are forced to spend a portion of their time in localities isolated from sources of information. To these the Library can render valuable service through correspondence; letters requesting information will receive special attention. The Library is prepared to furnish references and copies of articles on mining and metallurgical subjects; to determine the existence of mining-maps, and to furnish general information as to the geology and mineral resources of all countries.

All communications should be made as definite as possible so that the information received may be what is desired and not include collateral matter which may not be of interest. The time spent in searching for such collateral matter will be saved, and the information will be sent more promptly and in more usable shape.

The members of the Institute can be of service to the Library by forwarding copies of mining-reports, maps privately issued, and similar material, which will be classified, indexed, and made available to other members. Suggestions for additions to the Library, either by purchase or personal solicitation as gifts, will be welcomed. It is hoped that members while in the city will use the Library freely, and assurance is given that most careful service will be rendered to them.

LIBRARY ACCESSIONS

New Books on Mining, Metallurgy, and Chemistry

- MINING COPPER ORES AT MESSINA. By J. A. Woodburn. N. p., n. d. (Gift of Messina (Transvaal) Development Co., Ltd.)
- MESSINA MINE. The only producing copper mine in the Transvaal. November, 1913. (Gift of Messina (Transvaal) Development Co., Ltd.)
- LES MINÉRAIS DE FER DU LAC SUPÉRIEUR (Etats Unis). By H. Engelbach. (Gift of Author.)
- HANDBUCH DER MINERALCHEMIE. By C. Doelter. Ed. II, pt. 4. Dresden, 1913.
- HANDBUCH DER PRÄPARATIVEN CHEMIE. By Ludwig Vanino. Zwei Bände. I. Band—Anorganischer teil. Stuttgart, 1913.

New Books on Geology and Mineral Production

- ECONOMIC GEOLOGY. By C. H. Richardson. McGraw-Hill Book Co., New York, 1913.
- BRITISH GUIANA. Gold, Diamond, and Forest Industries. Report 1912-1913. Georgetown, 1913. (Gift of Hill Publishing Co.)

ANNUAIRE UNIVERSAL DES MINES ET DE LA MÉTALLURGIE, 1913-1914. By Robert Pitaval. Paris, n. d.

New Books on Non-Metallic Minerals

CARNOTITE. The principal source of radium. By T. F. V. Curran. New York, 1913. (Gift of Curran & Hudson.)

PRODUCTION OF COAL AND COKE IN CANADA, 1912. Ottawa, 1913.

PRELIMINARY REPORT ON URANIUM, RADIUM, AND VANADIUM. Bull. No. 70, U. S. Bureau of Mines, Washington, 1913.

OIL PRODUCTION METHODS. By P. M. Paine and B. K. Stroud; with a chapter on Accounting Systems, by W. F. and W. B. Sampson. Western Engineering Publishing Co., San Francisco, 1913. Price \$3. (Gift of Publishers.)

[NOTE.—A book for the practical man. After 50 pages on the distribution, properties, and uses of petroleum, the remainder of the book is devoted to the practice of oil-well drilling, going into extreme detail. The last chapter is devoted to accounting systems. The book describes California practice.—W. P. C.]

New Books on General Subjects

CLAYWORKER'S HANDBOOK. Ed. 2. By A. B. Searle. London, 1911.

TREATISE ON COST ACCOUNTING AS APPLIED TO COAL MINING. By J. J. Roby. Cleveland, 1913.

Company Reports

DE BEERS CONSOLIDATED MINES, LTD. Twenty-fifth Annual Report, 1913. Kimberley, 1913.

LOBITOS OILFIELDS, LTD. Report and Accounts for the years ended Dec. 31, 1911, 1912. London, 1911-12.

—Report of the Proceedings of 4th and 5th annual meetings 1912, 1913. London, 1912-13.

TRANSVAAL CHAMBER OF MINES. Twenty-second and twenty-third Annual Reports. Johannesburg, 1912-13.

Trade Catalogues

ALMY WATER TUBE BOILER Co., Providence, R. I. Sectional water-tube boilers Ed. 12, 1914.

AMERICAN ZINC ORE SEPARATING Co., Denver, Colo. Profitable handling of ores containing zinc. 10 pp.

ATLAS CAR & MANUFACTURING Co., Cleveland, O.

Bull. No. 1090. Electric locomotives, trucks and cars.

Bull. No. 1155. Storage battery locomotives.

Bull. No. 1160. Storage battery tractors and freight trucks.

Catalogue No. 1135. Different types of locomotives and cars for mines, etc.

BAKER PATENT SUSPENSION TYPE STORAGE BIN. An illustrated description. 26 pp. CHICAGO PNEUMATIC TOOL Co., Chicago, Ill.

Bull. No. 149. Chicago portable mine hoist. October, 1913.

ELECTRIC WEIGHING Co., New York, N. Y. Electric conveyor scales, Messiter patents.

JEFFREY MANUFACTURING Co., Columbus, O.

Bull. No. 32 B. Coal and ashes handling machinery in power plants.

Bull. No. 41 A. Single-roll coal crusher.

LESCHEN, A. & SONS ROPE Co., St. Louis, Mo. Leschen's Hercules. January, 1914.

NORTH WESTERN EXPANDED METAL Co., Chicago, Ill. Expanded metal construction. January, 1914.

SPARTA IRON WORKS Co., Sparta, Wis. Sludge bucket. November, 1913.

SPRAY ENGINEERING Co., Boston, Mass.

Bull. No. 23. Sprays for cooling condensing water.

SULLIVAN MACHINERY Co., Chicago, Ill.

Bull. 58 P. Single-stage, power-driven air compressors. December, 1913.

Bull. 58 S. Sullivan angle-compound, power-driven air compressors. December, 1913.

UNITED IRON WORKS, Oakland, Cal. Folder No. 49. Latest improved Huntington centrifugal roller quarts mill.



READING ROOM, ENGINEERING SOCIETIES' LIBRARY.

MEMBERSHIP

NEW MEMBERS

The following list comprises the names of those persons who became members during the month of January, 1914.

Members

- ADIASSEWICH, ALEXANDER, Dept. of Commerce & Industry,
11, Nadejdinskaia, St. Petersburg, Russia.
- BEARD, JOHN W., Mine Supt., Lane-Rincon Mines, Inc.,
Temascaltepec, Mex., Mexico.
- BORCHERDT, WALTER O., Supt. The Bertha Mineral Co., Austinville, Va.
- BREWSTER, BURT B., Sales Engr., Sullivan Machinery Co.,
1127 Central National Bank Bldg., St. Louis, Mo.
- CHASE, ROGER E., JR., Assayer 3906 No. Baltimore St., Tacoma, Wash.
- CULBERT, J. VICTOR 784 Wellington St., London, Ont., Canada.
- DICKINSON, ALBERT W., Supt. of Mines Bevier, Mo.
- DODSON, T. M. Morea Colliery, Schuylkill Co., Pa.
- FORREST, CHARLES N., Chem. Engr. Maurer, N. J.
- FOWL, FORREST M., Petroleum Engr., President Southern Pipe Line Co.,
26 Broadway, New York, N. Y.
- GORE, BANCROFT, Prof. Met. Mont. State School of Mines, Butte, Mont.
- GRUBNAU, VICTOR CARL, Met. P. O. Box 501, Palmerton, Pa.
- HALL, R. G., Metallurgical Engineer 3831 Baltimore Ave., Kansas City, Mo.
- HASSELBRING, ALBRACHT, Gen. Supt. Magpie Mine, Ont., Canada.
- HAWKS, HERBERT D., Commercial Engr., United Metals Selling Co.,
42 Broadway, New York City.
- HIRSHBERG, FRANK J., Min. Engr. 1535 Chapala St., Santa Barbara, Cal.
- LEDYARD, LEWIS W., Min. Engr. Cobalt, Ont., Canada.
- MCINTOSH, FRANK K., Mine Supt. Verona, Mich.
- MACCOY, FREDERICK, Asst. Mgr. Esperanza Mining Co., El Oro, Mex., Mexico.
- MARCH, FREDERICK C., Cons. Min. Engr.,
Broadway Court, Westminster, S. W., London, England.
- MARCH, HARRY, Cons. Min. Engr.,
Broadway Court, Westminster, S. W., London, England.
- MERRIMAN, THURSTON CABLES, Met. 352 Willow St., Waterbury, Conn.
- PERRY, EDWARD HALE, Geol., Secondary Enrichment Investigation,
135 Beacon St., Boston, Mass.
- POTTER, WINFIELD S., Prest., Alloy Steel Forging Co., Vice Prest., Manganese Steel
Rail Co., Manufacturers Bldg., Pittsburg, Pa.
- REED, HENRY B., Prest., Brothers Valley Coal Co. 90 West St., New York, N. Y.
- REMICK, WALTER L., Met. Sheep Creek, Juneau, Alaska.
- RICHARDSON, CLIFFORD, Cons. Engr. Woolworth Bldg., New York, N. Y.
- SAUNDERS, HENRY W., Div. Engr. U. S. Coal & Coke Co. Box 203, Gary, W. Va.
- SEARING, LEWIS, Vice-Pres. and Genl. Mgr., The Denver Engineering Works Co.,
Box 1802, Denver, Colo.
- SOHNLEIN, MAXIMILIAN G. F., Min. Engr.
c/o Cia. Minera de Oruro, Ingenio de Machacamarcas, Bolivia, South America.
- SORGE, KURT, General Mgr., Krupp-Grusonwerk Magdeburg-Buckau, Germany.
- STANTIAL, FRANK G., Chem. Engr. Everett, Mass.
- SULLIVAN, DAN P. Original Mine, Butte, Mont.
- WAGNER, WILLIAM HUFF, Min. Engr.,
c/o Spanish-American Iron Co., Santiago de Cuba.
- WISE, SIDNEY L., Min. Engr., Mines Management Co.,
60 Broadway, New York, N. Y.

Junior Members

- SCOTT, WAITER P., Student 804 Washington St., Moscow, Ida.
- SMITH, BERT F., Student 804 Washington St., Moscow, Ida.

CANDIDATES FOR MEMBERSHIP

The following persons have been proposed during the month of January, 1914, for election as members of the Institute. Their names are published for the information of members and associates, from whom the Committee on Membership earnestly invites confidential communications, favorable or unfavorable, concerning these candidates. A sufficient period (varying in the discretion of the Committee, according to the residence of the candidate) will be allowed for the reception of such communications, before any action upon these names by the Committee. After the lapse of this period, the Committee will recommend action by the Board of Directors, which has the power of final election.

Members

David T. Adams, Chicago, Ill.

Proposed by George A. Baird, Robert W. Hunt, D. W. McNaugher.

Born, 1859, Rockford, Ill. 1886, Discovered the Mesaba Iron Range. 1889, Made and compiled the first map of the range. 1889 to 1892, Discovered several mines, including the Sincanati, Kenowa, Lone Jack, New England, Bessemer, Victoria, Ohio, Meadow. 1892 to 1914, Discovered the Adams and the Fayal Mines, Palmer, Tener, Shenango Furnace, Cloquet Spruce, and other properties of the Mesaba; and now developing two mines on the Cuyuna Range.

Present position: Developing mining properties on the Cuyuna Iron Range, Minn.

Leland D. Adams, Weedon, P. Q., Canada.

Proposed by Richard C. Patterson, Jr., Eugene P. McCorken, Herbert S Kohlberg.

Born, 1886, Auburn, Cal. 1905-09, University of California, Mining. 1909, University of Arizona, Special Mining. 1910, Miami Copper Co., Engineer. 1911, Ray Cons. Copper Co.

Present position: 1912 to date, Manager of the East Canada Smelting Co., Ltd.

Eugenio Aguilera, Santiago de Cuba, Cuba.

Proposed by G. W. Pfeiffer, C. F. Rand, P. Aguilera.

Born, 1867, Bayamo, Cuba. 1874-77, Public Schools, N. Y. 1877-82, St. John's College, Fordham, N. Y. 1882-83, Bradford Mansion School, Rye, N. Y. 1883-87, Rensselaer Polytechnic Institute, Troy, N. Y.; C. E. 1888-94, Asst. Engr., Juragua Iron Co., Santiago de Cuba. 1893-94, Asst. Engr., Spanish American Iron Co., Santiago de Cuba. 1898-99, Asst. Engr., Ponupo Manganese Co., Santiago de Cuba.

Present position: 1899 to date, Chief Engineer of the Mining and Forestry Dept. of Santiago.

Chester Arthur Allen, Bodie, Cal.

Proposed by S. C. Wiel, C. E. Grunsky, Jr., H. F. Bain.

Born, 1886, Mass. 1902-06, Everett High School, Everett, Mass. 1908-13, Univ. of Cal., Berkeley, Cal.; B. S. 1906, Carpenter and Straw boss, F. B. Gilbreth, San Francisco. 1907, Foreman carpenter.

Present position: Asst. Supt., Stand. Cons. Min. Co., Bodie, Cal.

Paul Samuel Anderson, Baker, Ore.

Proposed by D. C. Bard, A. J. Schumacher, E. Melzer.

Born, 1870, Norway. 1886-96, Common School, Wis. 1897, Private School of Chemistry, Butte, Mont. 1898-99, Night School, private. 1900, Butte Business College. 1897-98, Miner, Hoisting Engineer and blacksmith, Oniada Mine, Butte, Mont. 1899, Assay Office, Parrot Smelter, Butte, Mont. 1900, Asst. Supt., Greenwood Milling Co., near Melrose, Mont. 1902, Supt., Western Mont. Cyanide Milling Co., Marting, Mont. 1904, Mont. Zinc Co. 1905, Supt. small cyanide plant near Baker. 1906-07, Supt., Silversmith and Apex Mines, Butte.

Present position: 1910 to date, Mgr. W. C. P. Co., Inc., Cyanide plants at Cornucopia, Highland Mines, Baker Co., Ore.

Frank Ashton Ayer, Morenci, Ariz.

Proposed by L. D. Ricketts, D. Cole, C. F. Rand.

Born, 1886, Keeseville, N. Y. 1899-1903, Saranac Lake High School, Saranac Lake, N. Y. 1904-05, Williams College, Williamstown, Mass. 1907-11, Columbia School of Mines, New York; E. M. 1905-06, Charge of Table Rock Oil Co. Prospects, Laceyville, Pa. 1906-07, Miner in Cobalt District, later in charge of prospecting party, Manhattan Cobalt Silver Co. 1908, Summer, Miner, New Jersey Zinc Co., Franklin Furnace, N. J. 1911, Asst. Geologist, Detroit Copper Co. 1912, Chief Sampler, Detroit Copper Co. 1912-13, Charge of Santa Rosa and Summit properties of Detroit Copper Co.

Present position: 1913 to date, Mine foreman, Yankee and Ryerson Mines, Detroit Copper Co.

George Charles Baer, Mogollon, N. M.

Proposed by Albert J. Anderson, Richard H. Britt, W. Rowland Cox.

Born, 1882, Sandusky, O. 1902, Graduated from Hillsdale High School. 1904-5, Student at Hillsdale College. 1907-10, New Mexico School of Mines; B. S. in Mining Engineering. 1910, Millman, Ozark Smelting & Min. Co., Kelly, N. M.; Chemist, Tri Bullion Min. Co., Kelly, N. M.; Mine Sampling and Examination with W. R. Cox at Mogollon, N. M. 1911-13, Filterman, Refining man, Mill Foreman, Mine and Timberman, Superintendent of Construction, Engineer, Socorro Mines, Mogollon, N. M.

Present position: Chief Engineer, Socorro Mining & Milling Co.

Harold Leslie Batten, Rossland, B. C.

Proposed by T. T. Read, R. E. Hore, H. E. T. Haultain.

Born, 1886, Singapore, Straits Settlement. 1894-97, Private. 1897-1904, Modern and Technical School, Northampton, Eng. 1902-03, Associate in Art, Oxon. 1908-11, Faculty of Applied Science, University of Toronto, Can. 1911, Grad. in mining engineering. 1911-12, Surveyor and Asst. Supt., Ontario Porcupine Goldfields Dev. Co., Ltd. (Bewick Moreing & Co., London). 1912-13, Shift boss, Inspiration Cons. Copper Co., Miami, Ariz. 1913, Assayer, Center Star and Trail. Asst. Mining Engineer, Le Roi Cons. M. & S. Co. of Canada, Ltd. 1907-11, Underground work for 2½ years as miner, timberman and shift boss.

Present position: Asst. Mining Engineer, Le Roi Mine, Rossland C. M. & S. Co. of Canada.

Donald Alexander Smith Bell, Morenci, Ariz.

Proposed by L. D. Ricketts, David Cole, A. Willis Clemes.

Born, 1889, Ottawa, Can. 1886-1900, Ottawa Model School. 1900-01, Natural History School (private). 1901-02, St. Albans School, Brockville, Ont. 1902-04, Public School, Ottawa. 1904-08, Ottawa Collegiate Institute. 1908-12, McGill University; B. S. in Mining Engineering. 1912-13, Miami Concentrator, Miami, Ariz., as sampler and operator.

Present position: Table repair and construction foreman No. 6 Concentrator, Arizona Copper, Morenci, Ariz.

Wheeler Scott Bishop, Toronto, Canada.

Proposed by G. A. Guess, H. E. T. Haultain, Charles F. Rand.

Born, 1882, Minneapolis. 1905, Cornell Univ.; A. B. 1905-07, Asst. to Supt., Standard Consolidated Mines Co., Prairie City, Ore. 1907, Chemist, Cananea Consolidated Copper Co. 1908, Milling and Mining in Nev. and Cal. 1909, Chemist, Tenn. Copper Co. 1910, Asst. Supt., Milan Mining & Milling Co., West Milan, N. H. 1911, Chemist, Tenn. Copper Co.

Present position: Lecturer in Metallurgy, Univ. of Toronto.

Everett L. Booth, Mayer, Ariz.

Proposed by S. R. Trengove, R. T. Walker, D. J. Evans.

Born, 1890, Northville. 1904-05, Erasmus Hall High School, Brooklyn, N. Y. 1905-07, Townsend Harris Hall, N. Y. 1907-09, College of the City of N. Y. 1909-12, Mich. College of Mines, Houghton, Mich.; B. S. and E. M. 1909, Assayer and Chemist for Libertad Mining and Smelting Co., San Antonio de la Huerta, Sonora, Mex.

Present position: 1912 to date, Mining Engineer with Swastika Development Co., Mayer, Ariz.

Maurice Sheldon Brandt, Boulder, Colo.

Proposed by Thomas T. Read, F. W. Traphagen, William R. Chedsey.

Born, 1883, Walton, N. Y. 1900, Walton High School, Walton, N. Y. 1904, Sheffield Scientific School; Ph. B. in Mining Engineering. Various correspondence school courses used as supplementary reading in Civil and Mining Engineering, 1904-05, Inter-ocean Mining Co., Sunshine, Colo. 1907, The United Globe Mines, Globe, Ariz. 1909, Federal Mining & Smelting Co., Warden, Idaho.

Present position: 1909 to date, Chief Engineer, White Eagle Mining & Milling Co., Sunshine, Colo.

Joseph C. Breinl, Pribram, Bohemia.

Proposed by H. M. Howe, William Campbell, E. L. Kurtz.

Born, 1874, Verseca. 1891, Realschule, Szeged. 1895, Eidgen. Polytechnikum, Zurich, Switzerland. 1910-12, Dozent, Technische Hochschule, Prag. 1913, Professor for mining and steelworks machinery plants, Pribram.

Present position: Professor of Montan-Hochschule, Pribram, Bohemia.

Albert D. Bryant, Palmerton, Pa.

Proposed by B. L. Miller, C. A. Wright, J. W. Richards.

Born, 1883, Austin, Texas. 1910, Grad. Mining Engineer, Lehigh Univ. 1913, Mining Engineer, Juragua Iron Co., Firmesa, Oriente, Cuba.

Present position: General Foreman, East Plant, New Jersey Zinc Co., Palmer-ton, Pa.

Thomas Barnes Burbridge, Cripple Creek, Colo.

Proposed by D. W. Brunton, F. M. Taylor, Howland Bancroft.

Born, 1861, Kentucky. 1875-78, Kentucky Military Academy, Hopkinsville, Ky. 1878, Work as Civil and Mechanical Engineer. 1896, Mgr., Cripple Creek Gold Hill Tunnel & Deep Mining Co. 1897, Vice-President and Mgr., Orphan Bill Mining & Milling Co. 1898, Owner and operating Coriolanus Mine.

Present position: 1913 to date, Owner and operator, Cripple Creek and Battle Mt. Mining District, Colo.

Richard Butler, Ulverston, Lancashire, England.

Proposed by F. W. Linck, C. F. Rand (one additional signature required).

Born, 1884, Barrow-in-Furness, England. 1903-06, Apprenticeship to Ed. Iachsen, C. & M. E., Whitehaven, Eng., General training in mining, surveying, etc. 1906-07, Asst. Engr., Whitehaven. 1907 to date, Studied Geology and Metallurgy, Technical School, Barrow-in-Furness, Certificates for mining, surveying, metallurgy, iron and steel manufacture, geology. 1903-06, Mine surveying in Iron Ore Mines, Cumberland. 1906, Moreasts Colliery Co's Pits, Cumberland. 1906-07, Asst. Engr. to George Doyd, Whitehaven, General surveying, railway, waterworks, and sewage.

Present position: 1907 to date, Harrison, Ainslie & Co., Ltd., Iron Masters, Ulverston, Lancashire, England, Employed in Genl. Management. Now Mine Supt.

John Lytle Caruthers, Raton, N. M.

Proposed by R. V. Norris, E. Renshaw Bush, Irving A. Stearns.

Born, 1886, Irwin, Pa. 1892-1904, Irwin Public School and High School. 1904-05, Bucknell University. 1905-08, Pennsylvania State College, School of Mines; B. S. 1908-09, Westmoreland Coal Co., as chairman. 1909-10, Colorado Fuel & Iron Co., Trinidad, Colo., as Asst. Engr. 1910-14, St. Louis, Rocky Mountain & Pacific Co., Raton, N. M., as Asst. Engr., under Frank A. Young, Chief Engineer of Mines.

Present position: Asst. Engr., St. Louis, Rocky Mountain & Pacific Co.

Patrick William Clark, Spokane, Wash.

Proposed by J. McD. Porter, L. K. Armstrong, R. H. Clarke.

Born, 1883, Butte, Mont. 1907-08, Asst. Mgr., Magistiel Mining Co., Old Mexico. 1909, Asst. Mgr., Nev. Treasure Mining Co.

Present position: Mgr. Bullwhacker Copper Co., Butte, Mont.

Collier Cobb, Chapel Hill, N. C.

Proposed by H. L. Smyth, E. D. Peters, W. S. Weeks.

Born, 1862, Wayne County, N. C. 1880-81, Univ. of N. C. 1886-89, Harvard; A. B. 1889-91, Grad. Student Harvard; 1894, A. M. 1888-90, Asst. in Geology, Harvard. 1890-92, Instructor in Geology, Mass. Inst. Tech. 1892-93, Asst. Prof. Geology and Mineralogy, Univ. N. C. Have done economic work in Montana, Tennessee, Georgia, Kentucky, and N. C.

Present position: 1893 to date, Professor of Geology and Mineralogy, Univ. of N. C.

Harry Comstock, Mineville, N. Y.

Proposed by S. LeFevre, S. H. Witherbee, F. S. Witherbee.

Born, 1880, Idaho Springs, Colo. 1887-96, Public Schools, Osawkie, Kans. 1896-1900, High School, Idaho Springs, Colo. 1902-05, A. & M. College, Stillwater, Okla.; B. S. 1900-01, Sun & Moon Mining Co., Idaho Springs, Colo. 1901-02, Gem Mining & Milling Co., Idaho Springs, Colo. 1905-07, General Electric Co., Schenectady, N. Y. 1907-13, Witherbee, Sherman & Co., Mineville, N. Y., Elec. and Mech. Engr., Asst. Genl. Mgr.

Present position: Genl. Supt.

Theodore Benton Counselman, Morenci, Ariz.

Proposed by D. Cole, L. D. Ricketts, C. F. Rand.

Born, 1889, New York City. 1906, Horace Mann School and High School. 1906-10, Columbia Univ.; E. M. 1910, Acme Graphite Co. of New York, Uwhland, Pa., Engineer. 1911, Brazos Syndicate, Velasco, Freeport, Tex., Sampler on rotary drills. 1911-12, Inspiration Consolidated Copper Co., Miami, Ariz., Rodman, transitman, draftsman, experimental mill. 1912-13, Cananea Consolidated Copper Co., Cananea, Sonora, Mexico, concentrator, mechanical draftsman, supply clerk, operating Peck machine. 1913, Ariz. Copper Co., Ltd., Morenci, Ariz., mechanical draftsman, sampler.

Present position: Efficiency Engineer, Concentrator No. 6, Arizona Copper Co., Ltd.

John Haskell Davis, Bisbee, Ariz.

Proposed by A. Notman, W. Douglas, G. Sherman.

Born, 1888, Belmont, Mass. 1910, A. B., Harvard. 1911, M. E., Harvard. 1911, Silver King Coalition Mining Co., Park City, Utah. 1911-14, Copper Queen Cons. Mining Co., Bisbee, Ariz., as Sampler, Engineer, and Geologist.

Present position: Geologist.

Henry Percy DePencier, New York, N. Y.

Proposed by E. F. Wood, D. H. Browne, W. W. Mein.

Born, 1875, Wakefield, Quebec, Can. 1882-89, Public Schools, Buckingham, Quebec, Canada. 1889-94, Public and High Schools, Vancouver, B. C. 1898-1903, McGill Univ., Montreal; Faculty of Applied Science; B. S. and M. S. 1894-98, Various minor positions connected with mining in British Columbia and Wash. State. 1903-04, H. Eckstein & Co. and subsidiary companies as surveyor and mining engineer. 1904-05, Underground Mgr., Princess Estate & Gold Mining Co., Ltd., Roodepoort, Transvaal. 1905-09, Genl. Mgr. Princess Estate & Gold Mining Co., Ltd. 1909-13, Private practice as Mining Engineer in Montreal, Can., and Johannesburg.

Present position: Asst. to Consulting Engineer, Canadian Mining & Exploration Co.

Kuno Doerr, El Paso, Texas.

Proposed by J. J. Ormsbee, A. Eilers, P. A. Mosman.

Born, 1873, Fort Madison, Iowa. 1890, Grad. Ft. Madison High School. 1893-94, Assayer, surveyor, Cedral Mines, near Villa de Musquiz, Mexico. 1894-95, Assayer and surveyor, Tepezala Mines, Tepezala, Ags., Mexico. 1895-99, Mining on own account and ore buying. 1899-1904, Ore purchasing agent A. S. & R. Co., Mexico. 1905-11, Mgr., Aguascalientes Smelter, A. S. & R. Co.

Present position: 1912 to date, Genl. Mgr., Consolidated Kansas City Smelting & Refining Co.

Walter Louis DuMoulin, Morenci, Ariz.

Proposed by L. D. Ricketts, D. Cole, C. F. Rand.

Born, 1882, Joliet, Ill. 1897, Grad. Public Schools, Joliet, Ill. 1901, Grad. High School, Pontiac, Ill. 1901-03, Student M. E., Univ. of Ill., Urbana, Ill. 1908, Grad. Rensselaer Polytechnic Institute, Troy, N. Y.; C. E. 1904-05, Draftsman, Old Dominion Copper Mining & Smelting Co., Globe, Ariz. 1908, Draftsman, Cananea Consolidated Copper Co., Cananea, Sonora, Mexico. 1909, Asst. to Cons. Engr., investigating waste heat utilization from oil-fired reverberatories and general power situation of Cananea Consolidated Copper Co. 1909-10, Asst. Supt. of Mech. & Elec. Work, Cananea Consolidated Copper Co.

Present position: 1910 to date, Supt. Morenci Water Co. of Morenci, Ariz. Charge of operation and additional installation.

Robert Baxter Elder, Chiksan, Korea.

Proposed by, J. J. Martin, J. S. Bradford, F. W. Traphagen.

Born, 1884, Normal, Ill. 1904, Grad. High School, Denver, Colo. 1908, Grad. Colo. School of Mines; Met. E. 1908-09, Chemist, Western Alkali Mfg. Co., Green River, Wyom. 1909-11, Aid, U. S. Coast and Geodetic Survey, work in Alaska and Northwestern States. 1911-12, Mine Foreman, Cimarron Mining Co., Smuggler, Colo.

Present position: Supt. Cyanide Plant, Chiksan Mines, Korea.

Rudolph Ericson, Iron River, Mich.

Proposed by T. F. Hildreth, C. F. Lawrence, G. R. Waeber.

Born, 1878, Ishpeming, Mich. 1896, Grad. Ishpeming High School. 1900-01, Chicago University extension. 1897-1902, Pittsburg & Lake Angeline Iron Co., Asst. Chemist and Mining Engineer. 1902-10, Chief Mining Engineer, Jones & Laughlin Steel Co.

Present position: 1910 to date, Supt. Davidson Ore Mining Co., Iron River, Mich.

Walter Fahringer, Audenried, Pa.

Proposed by D. Bunting, R. V. Norris, C. F. Huber.

Born, 1875, Jonestown, Pa. 1881-92, Public Schools. 1893-94, New Columbus Academy. 1895, Wyoming Seminary. 1896-1905, Employed at Mining Engineering as chairman, transitman, draftsman, etc., Lehigh & Wilkes Barre Coal Co. 1905-12, Division Engineer for Lehigh & Wilkes Barre Coal Co.

Present position: Division Supt., Lehigh & Wilkes Barre Coal Co.

Newton Crocker Fassett, Spokane, Wash.

Proposed by F. A. Ross, C. H. Goodsell, L. K. Armstrong, J. C. Haas.

Born, 1882, Germany. 1909, Mercersburg Academy. 1901-04, Cornell Univ.; C. E. 1904-05, C. M. Fassett Co., Spokane, Wash. 1905-09, Engineer and Assayer and actively engaged in mining, Nev. 1909-11, C. M. Fassett Co.

Present position: 1912 to date, President, The C. M. Fassett Co., Assayers, Chemists, etc.

Was a member of the Institute from 1905 until 1910.

Robert Faulkner, Lebanon, Pa.

Proposed by B. E. McKeehnie, R. H. Lee, B. D. Colman.

Born, 1883, Lowell, Mass. 1904, Mass. Inst. of Technology; Mining and Metallurgy; B. S. 1906-07, Nat. Galvanizing Works, Versailles, Pa. 1907, Concentrator, Goshen Iron Co., Rich Patch Mines, Va.

Present position: Asst. to Supt., Pa. Steel Co. Concentrator, Lebanon, Pa.

Charles Vaughan Ferguson, Schenectady, N. Y.

Proposed by H. G. Ferguson, W. R. Whitney, C. Van Brunt.

Born, 1885, Hartford, Conn. 1907, B. S., Trinity College, Hartford, Conn. 1911, Metallurgical Engineer, Harvard Univ. 1911-12, Asst. to Metallurgist, Carpenter Steel Co., Reading, Pa.

Present position: 1912 to date, Research Chemist, Research Laboratory, General Electric Co., Schenectady, N. Y.

Leon Feuchere, Bisbee, Ariz.

Proposed by A. Notman, W. Douglas, G. Sherman.

Born, 1878, Nimes, France. 1896, Bachelor lettres-sciences, lettres philosophie. 1900, Eleve de l'Ecole Nationale Supérieure des Mines, Paris. 1900, Admissible à l'Ecole Polytechnique. 1903, Ingenieur Civil des Mines. 1905-07, Cleveland Cliffs Iron Co., Ishpeming, Mich., Geologist. 1910, Mining Engineer at Tenn. River Coal Co., Tenn.

Present position: 1911 to date, Geologist with the Copper Queen Consolidated Mining Co.

Elected member 1906 but did not accept election.

Richard Rich Freeman, Jr., Ishpeming, Mich.

Proposed by M. F. La Croix, M. M. Duncan, H. L. Smyth.

Born, 1886, Wollaston, Mass. 1905, Boston Latin School. 1909, A. B., Harvard Univ. 1911, M. E., Harvard Univ.

Present position: 1910 to date, Cleveland Cliffs Iron Co., Mining Engineer.

George Clark Foote, Port Henry, N. Y.

Proposed by Arthur E. Hodgkiss, F. S. Witherbee, Lewis W. Francis.

Born, 1878, Port Henry, N. Y. High School, Port Henry, N. Y., and Williston Seminary, East Hampton, Mass. 1899, B. E., Union College. 1899 to 1902, Illinois Steel Co., So. Chicago, Ill., Transitman, C. E. Department, one and one-half years; Estimator, Asst. Blower; Asst. Supt., in charge of all furnaces at night, in Blast Furnace Department. 1902-05, Zenith Furnace Co., Duluth, Minn., as Superintendent. 1905-10, MacIntyre Iron Co., Albany, N. Y., as Manager and Treasurer. 1910-14, Witherbee, Sherman & Co., Port Henry, N. Y.

Present position: Resident Director of Witherbee, Sherman & Co.

George R. Gaenslen, Hurley, N. M.

Proposed by W. S. Hutchinson, H. O. Hofman, C. E. Locke.

Born, 1875, San Antonio, Texas. 1894, Grad. St. Louis College, General and Scientific Course. 1896-98, Studied Law. 1904, Grad. Mass. Institute of Technology, Boston, Mass.; S. B. Assayer Masch-Locke Mining Co., Sonora, Mex. 1904-05, Assayer and Asst. to W. S. Hutchinson on two mine examinations. 1905-06, Mine clerk and mine surveyor, Old Dominion Copper Mining & Smelting Co., Globe, Ariz. 1906, Millman, Foreman, Rincon Mines Co., Congress Jct., Ariz. 1907, Genl. Engineering. 1908-09, Assayer, Santa Rita Mining Co. 1910-12, Business for self.

Present position: Asst. Chemist, Chino Copper Co., Hurley, N. M.

Percy William George, Blubber Bay, Vananda, Canada.

Proposed by H. P. Fogh, Joseph Daniels, Milnor Roberts.

Born, 1880. Finished education at mining school of Falun, Sweden, October, 1900. 1900-01, Assist. to Bergmastare Th. Dahlblom, and working in Saxberget Concentr. Plant, Falun, Sweden. 1901-02, Assayer with Bergverks A. B. Vulcanus, Bjornhyttan, Grangesberg, Sweden. 1902-09, Min. Engr., Alten Copper Mines, and last four years Supt. of Kvanangen and Vaddasgaissa Copper Mines, belonging to Sulitelma Aktiebolag, Helsingborg, Sweden. 1909-11, Min. Engr., Cia. Real del Monte y Pachuca, Pachuca, Mexico, belonging to U. S. S. M. & R. Co. 1911-13, Mgr., Cia. Minera "La Cruz del Aire" S. S. Sabinas Hidalgo, N. L., Mexico, Zinc and lead mines, Mexico City, Mexico.

Present position: 1913 to date, Mgr., Texada Development Co., maj. belonging to same interests as Sulitelma Altoebolag, Helsingborg, Sweden.

Frank A. Glass, Brainerd, Minn.

Proposed by W. A. Barrows, Jr., C. Zapffe, C. H. Munger.

Born, 1883, Badger, Wis. 1904-05, Mont. State School of Mines. 1905-07, Mich. College of Mines; E. M. 1901-04, Clerk and engineers' asst., Boston & Montana Consolidated Copper & Silver Mining Co., Great Falls, Mont. 1907-08, Engineer, Rogers-Brown Ore Co. 1908-09, Engineer, Duluth Diamond Drilling Co.

Present position: 1910 to date, Private practice in mining and civil engineering, Montana, Idaho, and Arizona.

Thomas Clarence Gorman, South Porcupine, Ont., Can.

Proposed by C. E. Rodgers, H. C. Meek, T. I. Crowley.

Born, 1888, Ottawa, Can. 1907, Ottawa Collegiate Institute. 1906, Ottawa Univ. 1912, McGill Univ.; B. Sc. 1909, Rinaldo McConwell, Graphite Mine. 1911, Granby Mining, Smelting & Power Co., Ltd.

Present position: Sampler, Dome Mine.

William Lancelot Grace, St. Louis, Mo.

Proposed by Robert Linton, E. Gybbon Spilsbury, C. G. Atwater.

Born, 1878, St. Louis, Mo. St. Louis Public Schools, St. Louis University, Commercial College. Personal instruction and practice under mining engineers and operating officials in regard to iron ore examinations and operations, also studies in geology, mining and blast furnace work. 1901-02, Brown Ore Mining, Southeast Missouri. 1903, Brown Ore developing, near Ruak, Tex. 1904-06, Mgr., Western Whiting & Mfg. Co., Elsah, Ill., quarrying and crushing and grinding limestone. 1907, Genl. Mgr., Quinn Furnace Co., Gadsden, Ala., operating brown ore mines, Quinn, Merrelton and Rock Springs, Ala., also properties near Cedartown and Grady, Ga. 1908-09, Test pitting and concentration work, Missouri, for D. P. Thompson Syndicate, Inland Steel Co., Chicago, Ill. 1910-11, Diamond drilling in Missouri for D. P. Thompson Syndicate, also Llano, Tex., examination work. Part of 1912, examination and concentration work, Texas, under Robert Linton.

Present position: Iron ore examination and development work and personal investments.

Marcellus Fernando Graupner, San Francisco, Cal.

Proposed by H. L. Smyth, W. S. Weeks, H. P. Bain.

Born, 1873, Muscatine, Iowa. 1899-1900, Harvard College, Academic Dept. 1908-09, Mass. Institute of Technology, Boston, Mass. 1901-06, Work in the placer gold fields of Alaska. 1903-13, Prospected in Western States and northern Mexico. 1903-05, Trammer and mucker, Phelps, Dodge & Co., Bisbee, Ariz. 1907, Mucker and miner at Cerro Gordo silver, lead, zinc mine, Keeler, Cal. 1909-10, Mucker, in Calumet and Ariz. mines, Bisbee, Warren, Ariz.

Present position: 1907 to date, Mining, promoting and operating.

Ralph B. Green, Hayden, Ariz.

Proposed by H. T. Murray, D. D. Moffat, Charles F. Rand.

Born, 1865, Postville, Wis. 1890, B. S., Univ. of Wis. 1890-93, Chemist, Lake Superior Iron Co. 1894-1904, Minn. Iron Co. and the U. S. Steel Co. as chemist. 1904-07, Assayer and Supt. for the Oregon Smelting & Refining Co., Sumpter, Ore. 1907-08, Tacoma Smelting Co., Tacoma, Wash. 1908-11, Genl. yard foreman and Supt. for Balaklala Cons. Copper Co., Coram, Cal.

Present position: Asst. Supt., Hayden Plant, A. S. & R. Co., Hayden, Ariz.

Will Halloran, Albuquerque, N. M.

Proposed by Robert Linton, E. Gybbon Spilsbury, C. G. Atwater.

Born, 1888, Albuquerque, N. M. Until May, 1904, University of New Mexico, (Albuquerque). 1904-09, University of California, Berkeley, Cal. 1906-09, Western Pacific R. R. Survey, Nevada. Placer mining, Council District, Alaska. Mining, Copper Queen Co., Bisbee, Ariz. Mining, Construction, Mine examination, New Mexico and Colorado. 1910, Concentration experiments and mine surveying, Mochizuma Copper Co., Nacozari, Son., Mexico. 1910-12, Mine Foreman, Sierra Mining Co., Ocampo, Chih., Mexico. 1912, Concentration experiments, Mochizuma Copper Co., Nacozari, Son., Mexico. Mining, Butte & Superior Copper Co., Butte, Mont. Assisting Robert Linton on examination iron ore deposits, Texas. 1912-13, Mine examination for H. S. Munroe, Golden, Colo.

Present position: Mining Engineer, Halloran-Harlon Engineering Co., Albuquerque, N. M.

Charles Walter Hamilton, Tampico, Mexico.

Proposed by C. W. Hayes, David T. Day, E. W. Parker.

Born, 1890, Ithaca, Mich. 1904-08, Public High School, Ithaca, Mich. 1908-09, Alma College, Alma, Mich. 1909-10, National Preparatory Academy, Highland Falls, N. Y. 1910-12, University of Oklahoma; B. A. 1910, Private geological investigation in the Arbuckle Mountain, Oklahoma. U. S. & Okla. Geol. Survey (co-operative work) in the Oil Fields of Oklahoma. Associated with C. D. Smith, R. H. Wood and E. Z. Carpenter of the U. S. G. S. 1911, U. S. G. S. in the Williston District, N. D.

Present position: 1912 to date, Geologist for Cia. Mexicana de Petroles "El Aguila" S. A., Tampico, Mexico.

George Harding, Spokane, Wash.

Proposed by J. C. Haas, L. K. Armstrong, H. Kehoe.

Born 1878, Winnemucca, Nev. Public and High Schools, Oakland, Cal., Univ. of Cal., Berkeley, Cal. 1900-03, Cal. Wire Works, Designing, Constructing and erecting aerial tramways and mining machinery in Alaska and Northwestern States. 1903-1904, Bismarck Nugget Gulch Consolidated Mining Co., Branden, Mont., assaying, surveying and general engineering. 1904-1914, Consumers Co., Ltd.; Kootenai Power Co., Ltd.; Paulsen Building; Engineer and Mgr., Construction, Water System, Electric Light System, Power Plant, Pumping, Transmission Lines, Reservoir, etc.

Present position: Mgr. Consumers Co. and Kootenai Power Co., Coeur d'Alène, Idaho, and Paulsen Building of Spokane, Wash.

Samuel Pinkney Hatchett, Mogollon, N. M.

Proposed by Albert J. Anderson, Richard H. Britt, W. Rowland Cox.

Born, 1886, Valley Mills, Tex. 1904-06, Comanche High School. 1906-07, University of Texas, Academic Dept. 1908-11, University of Texas, Engineering Dept.; degree E. M. 1910, Filterman and Refiner, Socorro Mines. 1911-12, Batteryman, Tableman, Filterman, and in charge of Precipitation and Refining Depts., Socorro Mines.

Present position: 1912 to date, Assayer, Socorro Mining and Milling Co., Mogollon, N. M.

William Rust Haynie, New York, N. Y.

Proposed by L. Waldo, E. G. Spilsbury, W. N. Best.

Born, 1872, Front Royal, Va. Public Schools in Va., three years course in Bryant & Stratton School, St. Louis. Since 1900 have been occupied in laying out and constructing complete power plants for heat, light and industrial power, including Diesel electric power plants for copper mining and phosphate mining, with Hooven, Owens Rentschler Co.; Busch Sulzer Bros.; Diesel Eng. Co.; Covels Freres.

Present position: U. S. Rep. Covels Freres.

Arthur Hibbert, Brixton, S. W., England.

Proposed by Frank Merricks, L. H. Cooke, W. S. Bartlett.

Born, 1885, Manchester, England. 1907-10, Royal School of Mines, obtained diploma 1910. 1908, Admitted Institute of Mining and Metallurgy (London) as student. 1913, Transferred to Associate. 1910, Engaged by Anglo-Moroccan Mining Syndicate, Ltd., to survey the company's claims and prospect in Morocco. 1911, The Copper Mines of Copiapo, Ltd., engaged at Dulcinea Mine, Chile, as Assistant Engineer and Assayer. Appointed Acting Mine Manager and filled this position for nearly four months.

Present position: Acting Mine Manager.

Richard O. Hocking, Keewatin, Minn.

Proposed by Oscar B. Warren, A. P. Silliman, J. C. Agnew.

Born, 1886, Cornwall, England. 1891-1901, County Schools, Cornwall, England. Sept., 1910, Took course in metal mining in International Correspondence Schools, Scranton, Pa., and received diploma. 1902-05, Miner, South Wheel Croftis Tin Mine, Cornwall, England. 1905-10, Miner, Chapin Mine, Oliver Iron Mining Co., Iron Mountain, Mich. 1910-12, Asst. Engr. and Inspector, Meriden Iron Co., Hibbing, Minn. 1912-13, Mining Captain, Bennett Mine, Keewatin Mining Co., Keewatin, Minn.

Present position.: Asst. Supt. and Mining Captain, Bennett Mine, Keewatin, Minn.

Allen Hoffer, Pottstown, Pa.

Proposed by Edgar S. Cook, B. G. Klugh, Charles F. Rand.

Born, 1885, Lebanon, Pa. 1897-1904, The Hill School. 1904-07, Yale University. 1907, The Eastern Steel Co. At present with E. S. Cook—E. B. Cook.

Present position: Superintendent of Furnaces.

B. Edwin Hutchinson, New York, N. Y.

Proposed by T. S. Blair, Jr., J. C. Davis, B. A. Robinson.

Born, 1888, Chicago, Ill. 2½ years at the Mass. Inst. of Technology, class '09. Chief Engineer and Supt. of Open-Hearths at the Grand Crossing Tack Co., Steel Dept.; Chief Engineer of Blair Open-Hearth Furnace Co., Ltd., London, Eng. Vice-President of the Blair Engineering Co., 17 Battery Place, N. Y.

Present position: Vice-President, Blair Engineering Co.

Julius Curtis Ingersoll, Ouray, Colo.

Proposed by C. N. Bell, H. C. Lay, J. S. James.

Born, 1883, Denver, Colo. 1890-97, Grammar Schools, Denver. 1897-1901, West Denver High School. 1902-06, Colo. School of Mines; E. M. 1906, Colo. Smelting Co., Engineer and Assayer, Ironton, Colo. 1908, Atlas Mining & Milling Co., Engineering and surveying. 1910, Wanakah Mining Co., Engineer and surveyor. 1913, Mgr. Pony Min. Co., Pony, Mont.

Present position: 1908 to date, have been interested in general engineering business in Ouray, Telluride, and Denver, Colo. County Surveyor, Ouray County.

Jesse K. Johnston, Wilkensburg, Pa.

Proposed by S. A. Taylor, J. W. Boileau, H. B. Meller.

Born, 1867, Georges Sta., Pa. Greensburg High School. 1888, Penn R. R. 1891, Bailerton Belt Line R. R. 1892, Charleroi Coal Co. 1897, Pittsburg Plate Glass Co.

Present position: Vice-president and Genl. Mgr. Pitcairn Coal Co.

Alexander Blyth Jones, Idaho Springs, Colo.

Proposed by N. H. Beaton, C. W. Henderson, H. Lindsley.

Born, 1884, Hong Kong, Asia. 1889-92, Preparatory School. 1892-1900, Edinburgh Academy, Edinburgh, Scotland. 1902-05, Camborne School of Mines, Cornwall, England. 1906-07, Surveying, Le Roi Mining Co., Roseland, B. C. 1907, Surveying and assaying, White Bear Mining Co., Roseland; Surveying, Harper's Peak & Pacific Ry., Laramie, Wyo. 1909-11, Surveying and assaying, Kesley Mine, Ltd., Silver Centre, Ont. 1912-13, Assaying Wettlaufer Lorrain Silver Mines, Ltd. 1909-11, Prospecting and assessment work on claims.

Present position: Engineer, the Pozo Gilpin Co., Idaho Springs, Colo.

James Taylor Kemp, Palmerton, Pa.

Proposed by Charles P. Berkey, A. J. Moses, E. O. Hovey.

Born, 1890, Kingston, R. I. 1908-12, Student in Columbia College, last two years in the School of Mines; B. S. 1913, Asst. Engineer in exploration of oil shale concession, New Brunswick, Can.; Surveying Camp, Columbia Univ.

Present position: Sub-foreman, Zinc Smelter, New Jersey Zinc Co., Palmerton, Pa.

Frank O. Kichline, Bethlehem, Pa.

Proposed by P. W. Shimer, W. R. Shimer, W. L. Cumings.

Born, 1875, Easton, Pa. 1892, So. Easton High School. 1900, Lafayette College, Easton, Pa.; B. S. in chemistry. 1903, Lafayette College; M. S. 1895-1901, Proof-reader, Chemical Publishing Co., Easton, Pa. 1902-03, Chemist for Allegheny Ore & Iron Co., Clifton Forge, Va. 1904-05, Chemist for Juragua Iron Co., Santiago de Cuba, Cuba. 1906-14, Chemist for Bethlehem Steel Co., So. Bethlehem, Pa.

Present position: Chief Chemist, Saucon Plant, Bethlehem Steel Co.

Frederick Mills Kilmer, Jr., El Paso, Texas.

Proposed by J. J. Ormsbee, A. Eilers, P. A. Mosman.

Born, 1882, Arlington, Mass. 1888-99, Public Schools of Mass. 1899-1904, Harvard Univ.; S. B. in General Science. 1904-07, Mining Engineering in Colo. and Ariz. 1908, Efficiency engineering in piano factory. 1909, Mining in Colo. 1909-10, Engineer, Russell Construction Co. of Denver, Colo. 1910, Engineer in charge Orient Irrigation Co., Pecos, Tex. 1910-11, Mgr., Pecos Light & Ice Co., Pecos, Texas. 1911-12, Private practice in mining engineering.

Present position: 1912 to date, Engineering asst. to Supt., El Paso Smelting Works, El Paso, Tex.

Edward Robert Lidvall, Salt Lake City, Utah.

Proposed by E. Gayford, L. S. Austin, J. M. Callow.

Born, 1885, Dayton, Iowa. 1904, Grad. of Dayton High School. 1909, Grad. Iowa State College; B. S. 1909-10, Operator at Steptoe Valley Concentrator. 1910-12, Inspiration Consolidated Copper Co. 1912-13, Shift foreman at Cananea Consolidated Copper Co's Concentrator.

Present position: 1913 to date, Charge of General Engineering Co.'s public ore testing laboratory.

Robert Livermore, Cobalt, Ont., Canada.

Proposed by W. S. Weeks, H. L. Smyth, G. S. Raymer.

Born, 1876, Boston, Mass. 1900, Harvard; A. B. 1903, Mass. Inst. of Technology; S. B. 1903-04 Surveyor, Camp Bird Mining Co., Ltd. 1904-05, Lease on Stratton's Independence Mine, Cripple Creek, Colo. 1906-10, Lease on Smuggler Union Mining Co., Telluride, Colo. 1910-11, Examinations, Lindsley & Livermore, Boston, Mass.

Present position: 1911 to date. Mgr. Kerr Lake Mining Co., Ltd., and Wettlaufer Lorrain Silver Mines, Ltd., Cobalt, Ont., Canada.

Leon Root Long, Ecuador, So. America.

Proposed by A. L. Kelley, T. W. Mather, Rush W. Hess.

Born, 1884, Amboy, Ill. 1905-07, So. Dak. School of Mines, Rapid City, S. D. 1907-10, Mackay School of Mines, Reno, Nev. 1910-11, Assayer and Surveyor for Union Abitibi Mining Co., Larder City, Ont., Can. 1911-12, Metallurgist, La Libertad Mining Co., La Libertad, Nicaragua, C. A. 1912-13, Assayer, St. Louis M. & M. Co., Marysville, Mont.

Present position: Surveyor for the So. American Development Co.

Wilson Thomas Lundy, Weedon, Quebec, Canada.

Proposed by R. C. Patterson, Jr., H. S. Kohlburg, E. McCracken.

Born, 1884, San Francisco, Cal. 1907, Grad. Mining College of Univ. of Cal.; B. S. 1907-08, Copper Basin Mining Co., White Pine Co., Nev. 1908-12, Oriental Consolidated Mining Co., Unsan, Korea. 1912-13, North Star Mines Co., Grass Valley, Cal. 1913, Empire Mines, Grass Valley, Cal.

Present position: Asst. Supt., McDonald Mine, for East Canada Smelting Co., Ltd., Weedon, Quebec, Canada.

Walter Mathesius, Charlottenburg, Germany.

Proposed by E. Stutz, H. M. Howe, J. W. Richards.

Born, Giegnitz i. Schlerien, Germany. 1882, Diplom examen für Hüttenkunde an der Techn. Hochschule zu Charlottenburg. 1904, Professor of Metallurgie a. d. Techn. Hochschule, Charlottenburg. 1882-84, Chemiker-Ingenieur in Hochofen und Stahlwerksbetriebe der Hoerden Bergwerks und Hüttenvereins zu Hoerde, Westf. 1884-1900, Ingenieur, späten Theilhaben der Firma Ful. Golding und v. d. Heyde, Maschinenfabrik und Eisengiesserei i. Hoerde, Westf. 1900-02, Technischen Direktor derselben Firma nach Umwandlung in Eine Act. Ges. 1902-04, Oberingenieur d. Firma Th. Goldschmidt Chemische Fabrik und Zinnhütte, Essen Ruhr.

Present position: Professor an der Kgl. Techn. Hochschule, Charlottenburg.

Wallace George Matteson, So. Bethlehem, Pa.

Proposed by B. L. Miller, J. W. Richards, Henry S. Drinker.

Born, 1887, Pattersonville, N. Y. 1909, B. S. in Electrical Engineering and Science, Syracuse Univ. 1911, E. M. and E. Met., Colo. School of Mines, Geologist, International Construction Co., Haines, Alaska. 1912, Asst. Chief Engineer, Santa Gertrudis Mine, Pachuca, Hidalgo, Mex. Chief Engineer, Masopit Copper Co., Concepcion del Oro. 1913, Mine Boss, Cananea Consolidated Copper Co., Cananea, Sonora, Mex.

Present position: Instructor, Petrology and Mineralogy, Lehigh Univ., So. Bethlehem.

Mark Stephen Mazany, Hayden, Ariz.

Proposed by H. T. Murray, D. D. Moffat, Charles F. Rand.

Born, 1886, Dunkirk, N. Y. 1904-07, Student, Colgate Univ., Hamilton, N. Y.; R. S. course. 1909, B. S., Missouri School of Mines, Rolla, Mo. 1909-12, Asst. Assayer, Converter man, Furnace man, etc., Garfield Plant, A. S. & R. Co., Garfield, Utah.

Present position: Shift foreman, A. S. & R. Co., Hayden Plant, Hayden, Ariz.

Alan Frazer McCormick, El Paso, Texas.

Proposed by J. J. Ormsbee, A. Eilers, P. A. Mosman.

Born, 1874, Peter Island, Ont., Can. 1901-05, Chemistry, assaying and mech. drawing with International Correspondence Schools. 1899, Special course in chemistry and assaying, Washington State Agricultural and School of Science, Pullman, Wash. 1897-1900, Trail Smelting & Refining Co., Trail, B. C. 1900-05, Granby Consolidated S. & M. Co., Grand Forks, B. C., labor, sample hucker, machinist,

assayer and chemist. 1904, B. C. Assayer' examination. 1904-05, jigman, Hienze's Concentrator at Basin, Mont. Chief chemist for Le Roi mine at Rossland, B. C., and Bullion Smelter, Bullion, Mont. 1905, Chief chemist, Yampa Smelter, Highland Boy Smelter, Utah. 1905-06, Mine chemist, Nev. Consolidated Copper Co. 1906-09, Chemist, engineer, asst. supt. S. V. S. Mining Co. 1909, Anaconda, Great Falls and Northern Mich. Smelters.

Present position: 1912 to date, Asst. Supt., Cons. Kansas Smelting & Refining Co.

Charles Ellison McQuigg, State College, Pa.

Proposed by W. R. Crane, H. D. Pallister, C. W. Goodale.

Born, 1885, Ironton, Ohio. 1909, Ohio State Univ.; E. M. 1907-09, Asst., Dept. of Metallurgy and Mineralogy, Ohio State Univ. 1909-10, Railroad Construction Work, G. C. & S. F. Ry., Texas. 1910-12, Boston & Montana Reduction Dept., Anaconda Copper Mining Co., Great Falls, Mont.

Present position: 1912 to date, Head of Metallurgy Dept., School of Mines, Pa. State College.

Albert Richard Meyer, Brookline, Mass.

Proposed by H. L. Smyth, W. S. Weeks, C. H. White.

Born, 1876, Brookline, Mass. 1888, Private school in Brookline, Parish School in Brookline. 1890, Private School, Boston. 1895-98, Special student, Brookline, and Cambridge. 1899, Work as a miner at Jarilla Camp, N. M., Orion Mining Co. of El Paso, R. Tex. 1901, Shakespeare Camp, Lordsburg, N. M.

Present position: Unemployed owing to illness.

Hugo Walter Miller, Nogales, Ariz.

Proposed by J. E. McIntyre, J. Bond, H. G. Glore.

Born, 1889, Ballinger, Texas. 1906-10, Mining Dept., State Univ. of Texas; E. M. 1910-11, Asst. Engr., Santa Rita, New Mexico, Chino Copper Co. 1911-12, Chief Assayer and Chemist, Socorro Mines Co., Mogollon, N. M. 1912, Refinery Dept. of Cyanide Mill of Socorro Mines Co. 1912-13, Assayer and Engineer, Day Bristol Consolidated Mines Co., Pioche, Nev. 1913-14, Assayer and Engineer, Northern Sonora and Nogales, Ariz.

Present position: Assayer and Engineering Office, Nogales, Ariz.

William Millward, Chicago, Ill.

Proposed by T. S. Blair, Jr., R. Crooker, J. Kennedy.

Born, 1870, Cincinnati, Ohio. 1877-89, Public Schools, technically by tutor association and personal applications. 1889-90, Morgan Engineering Co., Alliance, Ohio. 1891-92, Carnegie Steel Co. 1893-94, Illinois Steel Co. 1894-95, Lorain Steel Co. 1895-96, Carnegie Steel Co. 1897-99, Jones & Laughlins, as engineer and supt. construction. 1900-02, Julian Kennedy, as engineer and designer. 1902-03, Victor Bentine, chief engineer and supt. construction. 1903-05, Lackawanna Steel Co., as engineer. 1905-06, Carnegie Steel Co., steam engineer and inspector of machinery. 1908, Indiana Steel Co., Engineer.

Present position: 1909 to date, Blair Engineering Co, as Chief Engineer.

John Mocine, Wallace, Idaho.

Proposed by A. Burch, K. M. Simpson, J. K. Turner.

Born, 1877, Oregon. 1893-94, Oregon Agricultural College; M. E. 1899-1904 Bunker Hill & Sullivan M. & C. Co., Kellogg, Idaho. 1904-05, Miscellaneous, 1906-08, Snow Storm Mining Co., Larson, and Greenough, Mullan, Idaho. 1908-09, Idaho Smelting & Refining Co., Ponderay, Idaho. 1909-10, Snow Storm Mining Co., Larson, Idaho. 1911-12, Allas Mining Co., Whitehorse, Y. T. 1913, Snow Storm M. Co., Larson, Idaho; Goldfield Cons. Mines Co., Goldfield.

Present position: Mgr., National Copper Mining Co., Mullan, Idaho.

Franklin Moeller, Cleveland, O.

Proposed by S. H. Pitkin, H. C. Hale, W. J. Rattle.

Born, 1865, New York, N. Y. Early education in Private Schools; 2 years Columbia College. 1887, Graduated from Stevens Institute of Technology; M. E. 1887-8, Welsbach Inc. Gas & Light Co. 1880-90, Ingersoll-Sergeant Rock Drill Co. 1890-94, Webster, Camp & Lane Machine Co. 1894-96, Wm. A. Harris Steam Engine Co. 1896-1900, Guild & Garrison Steam Pump Co. 1900-02, Webster, Camp & Lane Machine Co. 1902-14, Wellman-Seaver-Morgan Co.

Present position: Engineer, Power & Mining Dept.

William F. Moenke, Sunrise, Wyo.

Proposed by E. S. O'Connor, W. R. Appleby, Peter Christianson.

Born, 1883, Le Sueur Co., Minn. 1901, High School, Henderson, Minn. 1906, School of Mines, Univ. of Minn., as Engineer of Mines. 1906, Miner in Portland Mine, Victor, Colo. 1906-10, Asst. Engineer, Colo. Fuel & Iron Co., Sunrise, Wyo. 1910-11, Asst. Engineer, Pickands, Mather & Co., McKinley, Minn.

Present position, 1911 to date, Chief Engineer, Colo. Fuel & Iron Co.

Eduardo I. Montoulieu, Havana, Cuba.

Proposed by H. L. Smyth, C. F. Rand, J. R. Villalon.

Born, 1883, Camaguey, Cuba. 1898, A. B., Univ. of Havana. 1899-1900, Training at W. Va. Univ., Morgantown, W. Va. 1904, B. S. M. E., Cum Laude, School of Mines, Harvard Univ. 1902, Draftsman, Cuba Railroad Co., Ciego de Avila, Cuba. 1904, Prospecting and exploring Iron deposits, Senado, Camaguey. 1904-06, Engineer in charge, the Development Co. of Cuba, Ceballos, Cuba. 1905, Prospecting and exploring the Van Sycker Copper Mine for the Development Co. of Cuba. 1906-08, Asst. Engr. Bureau Waters, and Sewers, City of Havana. 1912, Appointed by the Courts to classify mineral deposits of the Mayari zone for expert evidence required in legal proceedings.

Present position: 1908 to date, Division Engineer, Havana Sewer, and Paving Contract, City of Havana.

Bliss Moore, Hurley, N. M.

Proposed by John M. Sully, William F. MacDonald, Joseph W. Richards.

Born, 1884, Provo, Utah. 1903-05, Gordon Academy (High School Course), Salt Lake City, Utah. 1906-08, Colorado College, Colorado Springs, Colo. 1900-01, Working in machine shop, Ajax Mine, Mammoth, Utah. 1902, Station tending at Carisa Mine, Robinson, Utah. Summer 1904, Trammings at Silver King mine, Park City, Utah. Summer 1905, With John Patience Fraser, Ajax Mine, Mammoth, Utah. Summer 1906, Machineman, Portland Mine, Victor, Colo. Summer, 1907, Prospecting in Uintah Mountains, Utah. 1909-10, Asst. Engr., in charge of underground engineering work, Utah Copper Co., Bingham Canyon, Utah. Engineer in charge of Churn Drill prospecting work. 1910-11, Transmittan for Chino Copper Co., Hurley, N. M. 1912-14, Engineer, Chino Copper Co.

Present position: Engineer at the Hurley Plant.

Samuel Albert Mory, London, Ky.

Proposed by G. Lewis, J. M. Clark, C. E. Krebs.

Born, 1869, Berne, Switzerland. 1885, Grad. High School, "Freies Gymnasium," Berne, Switzerland. Studied surveying by correspondence. 1896-1906, Practice land surveying and work for general custom. 1906-08, County Surveyor of Laurel County.

Present position: 1906 to date, Made surveys and maps and located shafts, etc., for the following coal companies: New Laurel Coal Co., Pitman Coal Co., Pittsburg Coal Co., Acme Coal Co., Pittsburgh, Ky.; Star Coal Co., Old Diamond Coal Co., East Bernestadt, Ky.; Ideal Block Coal Co., Lily, Ky.; New Bell Jellico Coal Co., Bell Jellico, Ky.

Ludrig L. Mussingbrod, Garnet, Mont.

Proposed by W. O. Crosby, H. O. Hofman, R. H. Richards.

Born, 1881, Mannheim, Germany. 1887-92, Public School, Ludwigshafen, Germany. 1892-97, High School, Mannheim, Germany. 1903-04, Maschinenbauschule, Berlin, Germany. Two and one-half years Mechanical Academy, Berlin, Germany; M. E. Four years machine shop work, Germany. One and one-half years practical work in Smelter, Int. S. & R. Co., Toole, Utah. Five years mining in Garnet, Mont., First Chance Mining Co., Mitchell & Mussingbrod, part owner.

Present position: Working mine at Garnet, Mont.

Stanley Lewis Nason, Mineville, N. Y.

Proposed by F. S. Witherbee, L. W. Francis, F. L. Nason.

Born 1887, Troy, N. Y. High Schools, West Haven and New Haven, Conn. 1910, Technical education, Rolla School of Mines, Rolla, Mo. 1910, Witherbee, Sherman & Co., Inc., Iron Miners, Mineville, N. Y. Asst. in magnetic survey: draftsman, supt. of construction, mine helper, asst. in magnetic concentrating mills, Supt.

Present position: Supt. Concentration mills, Mineville, N. Y.

Charles Patrick Neill.

Proposed by T. T. Read (two additional signatures required).

Born, 1865, Rock Island, Ill. 1885-88, Univ. of Notre Dame, Notre Dame, Ind. 1889-91, Georgetown Univ., Washington, D. C.; A. B. 1891-94, Instructor Mathematics, Notre Dame Univ. 1894-97, Johns Hopkins Univ.; Ph. D. 1897-1905, Instructor, Assoc. Prof., and Prof. Economics, Catholic Univ., Washington, D. C. 1905-13, U. S. Comm. of Labor. 1903, Asst. Recorder, Anthracite Strike Commission. 1904, Recorder, Alabama Coal Strike Arbitration Board. 1903-12, Sliding Scale Commissioner, under award of Anthracite Strike Commission. 1905-13, Empire of Anthracite Board of Conciliation.

Present position: Director in American Smelting & Refining Co., giving special attention to labor matters, including safety and sanitation.

George Dietrich Nordenholt, Los Angeles, Cal.

Proposed by F. A. Keith, S. W. Mudd, P. Wiseman.

Born, 1884, Oak Park, Ill. Grammar Schools, Oak Park, Ill. 1902, Grad. Oak Park High School. 1903, Univ. of Chicago. 1904, Univ. of Wis. 1905-09, Colo. School of Mines. Summer 1905, Surveyor, Port Clarence Mining Co., Teller, Alaska. 1909, Machine and timberman, Copper Queen, Bisbee, Ariz. 1909-11, Machine man, shiftman and foreman, Los Angeles Aqueduct. 1911, Supt. Domingo Mine, Keeler, Cal. 1912-13, Asst. Supt., Pacific Mine, Stagg, Cal. 1913, Supt., Idaho Mine Corporation, Edwardsburg, Idaho.

Present position: Mining Engineer.

Edward Page, Boston, Mass.

Proposed by T. W. Sprague, C. H. Davis, R. H. Richards.

Born, 1872, Newtonville. 1889-93, Mass. Institute of Technology. 1892-99, Employ of B. W. Hildreth & Co., N. Y., Inspecting Engineers. 1899, Commercial work, selling coal, iron and steel. 1905, Selling coal.

Present position: 1909 to date, Vice-President, Federal C. & C. Co. and charge T. B. B. Coal Co.

Arthur Clifford Parsons, Buffalo, N. Y.

Proposed by Charles F. Rand, A. H. Lee, E. A. S. Clarke.

Born, 1875, Enfield, Conn. 1897, B. A. at Amherst College. 1897-99, P. & R. R. as Asst. Chemist. 1899, National Steel Co. 1899-1906, Chemist for South Chicago Furnace Co., and International Harvester Co.

Present position: 1905 to date, Chemist for Lackawanna Steel Co., Buffalo, N. Y.

Dan Conley Peacock, Brainerd, Minn.

Proposed by W. A. Barrows, Jr., C. Zapffe, C. H. Munger.

Born, 1877, Escanaba, Mich. 1898, Grad. Mich. College of Mines; E. M. 1898-1903, Mining engineer, Commonwealth Iron Co., Commonwealth, Wis., and Beacon, Mich. 1903-08, Supt., Genl. Supt., Shenange Furnace Co., Hibbing, Minn.

Present position: Consulting Engineer.

Harold A. Pelton, Avila, Cal.

Proposed by A. R. Heise, C. A. Chase, W. B. Patrick.

Born, 1888, Denver, Colo. 1907-09, Colo. School of Mines. 1903-07, Manual Training High School. 1909-10, Inst. man, Arnold Eng. Co., Chicago, Ill. 1910-11, Genl. mill work, Mogul Mill, Pluma, S. D.; Wilson Mill, Kokomo, Colo. 1911-13, Private Practice as surveyor and chemist.

Present position: 1913 to date, Chief Chemist, Avila Refinery, Union Oil Co. of Cal.

Walter Lampton Reid, Telluride, Colo.

Proposed by B. Wells, C. N. Bell, H. C. Lay, J. S. James.

Born, 1875, Trenton, Mo. 1900-01, Peck Cyanide Plant, Telluride, Colo. 1901-02, Mill of Liberty Bell Gold Mining Co., Telluride, Colo. 1902 to date, Cyanide Plant of the Smuggler Union Mining Co., Telluride, Colo.

Present position: Superintendent.

William Henderson Rettie, Yonkers, N. Y.

Proposed by Bradley Stoughton, J. T. Magee, C. F. Rand.

Born, 1886, Aberdeen, Scotland. Public Schools of Yonkers. 1901-02, Birds Bronx Boro. Business Institute. 1903-07, N. Y. Evening High Schools. 1907-08, Columbia Extension Teaching; Engineering. 1912-13, Scranton Correspondence Schools. 1905-06, Topographical draftsman, Borough of Bronx. 1906-07, Surveying, F. G. Fowler. 1908-11, Transitman, Catskill Aqueduct. 1913, Foreman, Sewer Construction, Rodgers & Hagerty.

Present position: with City of Yonkers, N. Y.

Leo Bowiby Reynolds, Nelson, B. C.

Proposed by F. E. Pearce, A. H. Gracey, C. F. Rand.

Born, 1875, Waterford, Ont. 1903, Grad. in mining, McGill Univ. Three years practical mining, assaying, surveying in Western States. In dept. of metallurgy at McGill Univ. on electric smelting of lead and zinc ores, holding in conjunction with Dr. Stansfield basic patents in same.

Present position: 1908 to date, Mgr., Eureka Copper Mines.

William Frank Roberts, South Bethlehem, Pa.

Proposed by E. O'C. Acker, W. L. Cumings, W. R. Shimer.

Born, 1879, Luzerne Co., Pa. 1898-1902, Lehigh Univ.; M. E. 1891-98, Coxie Bros. & Co., Drifton Pa., asst. in laboratory.

Present position: 1902 to date, Bethlehem Steel Co., Supt. of Boilers, Master Mechanic, Asst. Genl. Supt. Now Genl. Supt.

John F. Robertson, Coniston, Ont., Canada.

Proposed by A. W. G. Wilson, H. Frechette, L. H. Cole.

Born, 1880, Charlottetown, P. E. I. 1895-98, Prince of Wales College, Charlottetown, P. E. I. 1898-1904, McGill Univ., Montreal; B. Sc. and M. Sc. 1904, Surveyor mining dept. B. C. Copper Co., Greenwood, B. C. 1904-07, Lecturer in Mining Engineering, McGill Univ. 1907, On Construction, Mining Dept. B. C. Copper Co.

Present position: 1907 to date, Smelter Supt., Mond Nickel Co., Victoria Mines and Coniston, Ont.

Fred Gore Rockwell, Ishpeming, Mich.

Proposed by M. F. LaCroix, L. Eaton, E. E. White.

Born, 1885, Towanda, Pa. 1892-1904, Towanda Public Schools. 1905-09, S. B., Harvard Univ. 1909-10, Vega Grande Copper Co., Cuba. 1910, Cleveland Cliffs Iron Co.

Present position: Geologist, Cleveland Cliffs Iron Co.

Isidro G. Jauregui y Rodriguez, Santiago de Cuba.

Proposed by P. O. Persing, G. W. Pfeiffer, Charles F. Rand.

Born, 1879, Havana. 1898, Grad. San Basilio el Magno College, Santiago de Cuba. 1910, Grad. Villanova College, Penn.; B. S. in Civil Engineering. 1899-1902, Municipal Engineering Dept., City of Santiago de Cuba. 1902-06, Engineering Dept., El Cobre Mines Co., Santiago de Cuba.

Present position: 1910 to date, Asst. Engr., Spanish American Iron Co., Santiago de Cuba.

Osborn Peabody Rogers, Kensington, Alaska.

Proposed by J. R. Whipple, B. L. Thane, B. B. Nieding.

Born, 1882, Madisonville, Ohio. 1888-1902, Common and High Schools, Madisonville. 1910-11, Ohio State Univ., Special Student Metallurgy. 1902-09, Chairman, Transitman, Fairmont Coal Co., Fairmont, W. Va.; Transitman Consolidated Coal Co., Frostburg, Md. 1904-05, Transitman, Asst. Engr., New River Smokeless Coal Co., Rush Run, W. Va. 1905-06, Mine Engr., Suhrig Coal Co., Suhrig, Ohio. 1906-08, Division Engr., Utah Fuel Co., Castle Gate, Utah. 1908-09, Traveling in Europe. 1909-10, Practical Miner and Millman, Eagle River Mining Co., Amalga, Alaska. 1912, Engr., Kensington Mining Co., Kensington, Alaska; Engr., Sheep Creek Tunnel, Alaska Gastineau M. Co., Juneau, Alaska.

Present position: Engr., Kensington Mining Co.

William N. Rossberg, Butte City, Mont.

Proposed by R. S. McCaffery, C. A. Stewart, F. Jenkins.

Born, 1881, Phoenix, Mich. 1904, E. M., Columbia School of Mines. 1905, Asst. Supt., Peck Centrifugal Separating Co., Frisco, Utah. 1906-08, Supt. and Genl. Supt., Fortuna Mine, and of Carisa Mining Co., Eureka, Utah. 1909-10, Mining Engineering and Metallurgical work.

Present position: Metallurgical Engineer, Clarke Interests, Butte, Mont.

Jessie Perry Rowe, Missoula, Mont.

Proposed by D. C. Bard, C. H. Bowman, R. H. Sales.

Born, 1871, Salem, Mich. 1897-1906, Univ. of Nebraska; B. S., M. A., Ph. D. 1901, Grad. Student, Univ. of Cal. 1905, Grad. Student, Univ. of Chicago. 1897-98, Fellow Univ. of Neb. 1906, Grad. Student Univ. of Neb. 1894-97, Asst., Dept. of Geology, Univ. of Neb. 1897-98, Instructor, Dept. of Geology. 1900-1914, Professor of Geology, Univ. of Montana. 1902-11, Director, Univ. of Mont. Geological

Survey. 1906-07, U. S. G. S., summers; examined and reported upon hundred of metal and non-metal mining properties.

Present position: Professor of Geology, University of Montana, Missoula.

Ward Royce, Gleeson, Ariz.

Proposed by J. Murray, W. G. McBride, J. E. Penberthy.

Born, 1882, Baraga, Mich. To 1898, Common Schools, Baraga, Mich., [Marquette, Mich., and Hammond, Ind. 1906-10, Mich. College of Mines; E. M. 1898-1901, Office boy, clerk, etc. 1901-04, Apprentices Machinist, P. L. & M. Co., Hancock, Mich. 1904-06, Machinist, Canal Fdry. Co., Houghton; Hodge Iron Co., Hancock, Mich.; Oiler, U. S. T. Co., etc. 1907-08, Asst. Engr., Pickands Mather Co.; Machinist, Adventure Copper Co. 1910-12, Engineer, shift boss, etc., Shannon Copper Co., Ariz. 1912-13, Engineer, Genl. Mine Foreman, 3 R. Mines, Patagonia, Ariz.; Engineer, Leonard Copper Co.

Present position: Mining Engineer, Leonard Copper Co., Gleeson, Ariz.

Frederick Rullman Schaefer, New York, N. Y.

Proposed by A. E. Borie, W. L. Wright, H. B. Gaylord.

Born, 1886, Chicago, Ill. 1900-06, Lewis Inst. of Technology, Chicago, Ill. 1906-08, Univ. of Mich., Ann Arbor, Mich.; S. E. and M. E. 1908-09, Chicago Telephone Co., Draftsman. 1909-11, H. W. Caldwell & Son Co., Chicago, Ill., Draftsman and Sales Engineer.

Present position: 1911 to date, District Sales Manager, Taylor-Wharton Iron & Steel Co., High Bridge, N. J.

James Ralph Scott, South Porcupine, Ont.

Proposed by H. C. Meek, W. A. Bostwick, W. W. Mein.

Born, 1887, Bay City, Mich. 1905-08, Olivet College, Mich. 1908-11, Mich. College of Mines; B. S. and E. M. Sampler, Rodman, Surveyor and Mine Engineer, Dome Mines.

Present position: Mine Engineer, Dome Mines.

William Hugh Shearman, New York, N. Y.

Proposed by R. V. Norris, Irving A. Stearns, E. Renshaw Bush.

Born, 1884, Brooklyn, N. Y. 1898-1901, L. I. City High School. 1902-10, Columbia University; E. M. 1904-05, Rodman, Tidewater Ry., Va. 1907-08, Land Agent and Asst. Engr., Birmingham Coal & Iron Co., Birmingham, Ala. 1910-11, Asst. Engr., New England Portland Cement Co., Rockland, Me. 1912, Assistant, Summer School, Columbia University. 1912-13, Engr., New Brunswick State Development Co., Turtle Creek, N. B., Can. 1913, Assistant, Summer School, Columbia University.

Present position: Assistant with R. V. Norris, Wilkes Barre, Pa.

Alexander Sibbald, Clifton, Ariz.

Proposed by N. Carmichael, J. Kiddie, F. Rutherford.

Born, 1889, Scotland. 1895-1907, Public and High Schools. 1907-12, College and working with a consulting engineer in Glasgow, Scotland. 1912-13, Engineering staff of The Old Dominion Copper Mining & Smelting Co., Globe, Ariz. 1913, Ariz. Copper Co. 1911-12, Asst. M. E. with the Glengarnock Iron & Steel Co., Ltd., Ardeer, Argyshire, Scotland.

Present position: Metallurgical Book-keeper.

John Skogmark, Martins Ferry, Ohio.

Proposed by F. E. Pierce, J. A. Van Mater, L. G. Rowand.

Born, 1877, Ore, Sweden. 1893, Grad. High School, Christinehamn, Sweden. 1897, Grad. Chalmers Institute of Technology, Gothenburg; M. E. and E. E. 1897-98, Jonserseds Mfg. Co., Jonsered, Mechanical Draftsman. 1898, Public Works, City of Gothenburg. 1900, Waterworks and Harbor Construction. 1900-12, City of Falkenberg, Waterworks Construction. 1903-04, Industrial Works, Bay City, Mich., Machine Designer. 1904, Isthmian Canal Commission. 1905, Master Mechanic at Culebra, Bucyrus Co., South Milwaukee, Wis. 1906, Steam Shovel and Dredge Construction, Raritan Copper Works, Perth Amboy, N. J. Mechanical Engr., Extension to Copper Refinery. 1907-09, Cerro de Pasco Mining Co., La Fundicion, Peru, S. A. 1910, Mineral Point Zinc Co.

Present position: Metallurgical and Construction Engineer with the Mineral Point Zinc Co.

Savannah Johnson Speak, London, England. 1854

Proposed by E. Hooper, T. A. Rickard, A. R. Weigall.

Born, 1868, Yorkshire, England. To 1883, High School, Shipley, Yorkshire. 1883-86, Yorkshire College, Leeds. 1886-89, Royal School of Mines, London; A. R. S. M. 1890-91, Asst. Engr. South African Finance & Prospecting Syndicate. 1891, Asst. to the late Eugene Hofer, reporting in Damaraland. 1892-94, Lecturer on Metallurgy, Univ. of Sydney, N. S. W. 1895-97, Metallurgist, Geldenhuis Deep Gold Mines, Transvaal. 1898, Mgr., Kolchis Mijnbouw Waat, Dutch East Indies. 1899-1900, Mining Engineer, The Olavi Mines u. Eisenbahnen Ges., German S. W. Africa. 1900-01, Examining mines in West Africa. 1901-02, Supt. Oriental Consolidated Co., Korea. 1904-05, Mgr. Ymir Mine, British Columbia.

Present position: 1906 to date, Partner in firm of Hooper, Speak & Co., Mining Engrs. London, Siberia, and West Australia.

H. Norman Spicer, New York, N. Y.

Proposed by R. Linton, A. M. Robeson, E. G. Spilsbury.

Born, 1865, Hants, England. 1881-85, Manchester College. 1889, Mysore, India, Tank Block Mine. 1892, Mt. Lyall, Tasmania. 1894, Western Aust. Brown Hill G. M. Co., Great Tingall. 1898, Mgr., Hannans Gold Estates. 1901, Abbottiakoon G. M. Co., West Africa. 1903-05, Siberia, Genl. Mining Engineering, Con. Goldfields of S. A., Siberian Trust Co. 1907-10, Genl. M. E., U. S. A., Mexico.

Present position: Mgr. Dorr Cyanide Machinery Co., New York City.

Hugh Aloysius Stewart, Chiksan Mines, Korea.

Proposed by H. J. Wolf, J. J. Martin, J. S. Bradford.

Born, 1888, Aspen, Colo. Public Schools, Colo. and Cal. 1906, Grad. Brighton High School, Colo. 1908-12, Colo. School of Mines; E. M. 1906-08, Trilby Mines Co., Cripple Creek, Colo. 1912, Chiksan Mines.

Present position: Mine Supt.

Harry Patterson Sweeny, Stroudsburg, Pa.

Proposed by W. S. Hutchinson, R. H. Richards, C. E. Locke.

Born, 1883, Drifton, Pa. 1905, Yale College; B. A. 1908, Mass. Inst. of Technology; B. S. 1908-09, Chief of Party, Topographic Surveying for Westbrook & Voss, Stroudsburg, Pa. 1909-10, Chief Engineer, Maryland Coal Co. of Pa., St. Michael, Pa. 1910-12, Supt. Bache-Denman Coal Co., Fort Smith, Ark. 1912-13, Engr. with Westbrook & Voss, Stroudsburg, Pa.

Present position: 1913 to date, Engineer with Thomas Iron Co., Wharton, N. J.

Theodore Van Kleeck Swift, Mineville, N. Y.

Proposed by S. Le Fevre, S. H. Witherbee, L. W. Francis.

Born, 1887, Poughkeepsie, N. Y. 1903-05, Hotchkiss School. 1905-08, Yale Univ.; Ph. B. 1908-09, Copper Queen Cons. Mining Co., Bisbee, Ariz., Engineering Dept. 1909-10, El Tigre Mining Co., Sonora, Mexico. 1910-11, Wright & Livingston, Mining Engineering, Douglas, Ariz.

Present position: 1911 to date, Min. Engr., Witherbee, Sherman & Co., Inc., Mineville, N. Y.

Arthur Fay Taggart, New Haven, Conn.

Proposed by J. F. McClelland, L. W. Bahney, J. D. Irving, J. W. Roe.

Born, 1884, New York City. 1909, A. B., Stanford Univ. 1910, E. M., Stanford Univ. 1909, Engineering staff, Miami Copper Co. 1910, Summer, Sampler, Steptoe Valley S. & M. Co. 1910-11, Examination work, Bolivia.

Present position: 1911 to date, Instructor in Mining, Sheffield Scientific School

Richard Tarantous, Ray, Ariz.

Proposed by S. Paul Lindau, Louis S. Cates, R. C. Gemmell.

Born, 1887, New York, N. Y. 1904-08, College City of New York; B. S. 1908-09, Instructor Mathematics, DeWitt Clinton Public High School, New York City. 1909-12, Student, Columbia University; E. M. 1910-12, P. G. work in mathematical physics at Columbia. 1912-13, Mining Engineer, Shannon Copper Co., Metcalf, Ariz.

Present position: 1913 to date, Engineer, Ray Consolidated Copper Co., Ray, Ariz.

George William Teal, Boulder, Colo.

Proposed by E. LeN. Foster, F. H. Bostwick, C. L. Colburn.

Born, 1863, England. 1875-79, Schools, Georgetown, Colo. 1879-82, College, London, England. 1882-83, School of Mines, Freiberg, Germany. 1883-86, Assaying and mine surveying, Georgetown, Colo. 1886-87, Assaying and surveying for the Four Creeks M. & M. Co., New Mexico. 1887-97, City Engineer, Boulder, Colo.; County Surveyor, Boulder Co., Colo. 1897-1914, General engineering business. 1907-1914, Consulting Engineer and Mgr. of mines for the Primos M. & M. Co. Boulder, Colo., Tungsten mines. 1910-14, Consulting Engineer, Primos Chemical Co. vanadium mines, San Miguel Co., Colo. 1889-1914, United States Deputy Mineral Surveyor.

Present position: Mgr. of Mines, Primos Mining & Milling Co., Boulder, Colo.

James Brand Tenney, Bisbee, Ariz.

Proposed by Arthur Notman, Warren Douglas, Gerald Sherman.

Born, 1884, Shanghai, China. 1901, Graduated from St. Matthews Military School, San Mateo, Cal. 1907, Graduated from Columbia School of Mines; E. M. 1907-09, Engineer with the Liberty Bell G. M. Co., Telluride, Colo. 1909-11, Surveyor with the Copper Queen Cons. Min. Co.

Present position: 1911 to date, Geologist with the Copper Queen Cons. Min. Co.

Harold George Bissell Thomas, London, S. W., England.

Proposed by R. G. Brown, D. P. Mitchell, W. G. Perkins.

Born, 1885, Staffordshire. 1904, Mine Survey Dept. De Beers Consolidated, Mines, Kimberley, So. Africa. 1904-06, Surveyor, Dutoitspan Mine of the above Co. 1906, Taking course in electrical engineering, Central Technical College, London. 1906-09, Royal School of Mines, London, Grad. as Associate in depts. of mining and metallurgy. 1909-10, Fanti Consolidated Mines, West Africa, engaged on ore reserve valuations at their various properties. 1911-12, Asst. to H. C. Hoover, London. 1912, Charge Technical Dept. Tanalyk Corporation, Russia. 1913, Examination work in Hungary for T. J. Hoover, London; Examination work in Siberia for Russo-Asiatic Corporation, London.

Present position: Technical Staff, Russo-Asiatic Corporation, London.

John A. Topping, New York, N. Y.

Proposed by J. Gayley, C. F. Rand, J. E. Johnson, Jr.

Born, 1860, St. Clairsville, Ohio. Public and High Schools, Kansas City, Mo. 1877, Bank Clerk, Bellaire, Ohio. 1878, Iron business as pay roll clerk, Aetna Iron & Nail Co. 1898, Pres. of Aetna Co. 1900, 1st V. P. American Sheet Steel Co. 1903, Reorganized La Belle Iron Works, Wheeling, W. Va. 1904, Pres. Am. Sheet & Tin Plate Co. 1906, Pres. and Chairman, Republic Iron & Steel Co., and Tenn. Coal Iron & R. R. Co.

Present position: 1907 to date, Chairman, Republic Iron & Steel Co.

Charles Samuel Vadner, Salt Lake City, Utah.

Proposed by E. A. Wall, Lewis A. Jeffs, R. C. Gemmell.

Born, 1870, North Adams, Mass. 1878-83, Drury Academy, North Adams, Mass. 1883, Preparatory Department, Ottawa University, Ottawa, Can., Learning French. 1889, Member Matriculating Class. 1892, Graduated as a Chemist from the Chemical Department of the Philadelphia College of Pharmacy. 1894, Post-graduate course at same institution in metallurgical analysis and assaying and industrial analysis. 1914, Master Science degree in Metallurgical Chemistry, to be granted at the 66th Annual Commencement in June, 1914, Ottawa University, Ottawa, Can. 1893, Metallurgical Chemist at Anaconda Smelter, Anaconda, Mont. 1895, Examining Pyrite Deposits in Hoosac Mountains near Zoar, Mass. 1896-98, Managing and developing property of Zelnora Mining Co., Bingham Canyon, Utah. 1903, Superintendent and Metallurgist, Winnemucca Gold Mining Co., Philadelphia. 1905, Examinations, office and metallurgical works, Battle Mountain, Nev.

Present position: Engaged in Research Work.

Arthur Mason Van Rensselaer, New London, Conn.

Proposed by H. L. Smyth, W. S. Weeks, G. S. Raymer.

Born, 1888, New York City. 1904-07, Irving School of N. Y. 1907-11, Harvard School of Mines; B. S. 1911-12, Bigelow Joslin Construction Co., Boston, Time-keeper and asst. to engineer in charge. 1912, Supt., Climax Co., Lowell, Plant at Montville, Ct.

Present position: 1912 to date, Thames River Specialties Co., Montville, Ct., Manufacturers of paper box-boards. Supt., Genl. Mgr., Asst. to President.

George B. Waterhouse, Buffalo, N. Y.

Proposed by E. A. S. Clarke, A. H. Lee, Charles F. Rand.

Born, 1883, Sheffield, England. 1887-98, Grade and High Schools, Sheffield. 1898-1903, Course in Metallurgy and special work in research, Univ. of Sheffield; B. M. 1903-06, Columbia Univ. Major in Iron and Steel Metallurgy, Minors in Geology and Chemistry; Ph. D. Summer, 1905, Lackawanna Steel Co., Metallurgical work.

Present position: 1906 to date, Metallurgical Engineer, Lackawanna Steel Co.

Stuart Sidney Webb-Bowen, London, England.

Proposed by Charles S. Herzig, A. F. Kuehn, Theodore J. Hoover.

Born, 1884, London, England. 1899-1901, Engineering Division, Dulwich College. 1901-04, Royal School of Mines, London. 1904-06, Post-graduate course under Messrs. Bewick, Moreing & Co., in West Australia. 1906-08, Chief Surveyor, Sons of Gwali Mines, West Australia. 1908-09, Scouting for H. C. Hoover and Assistant to C. S. Herzig in Nicaragua. 1910, In charge resampling Prestea Block "A" Mine, G. C. C., West Africa. 1911, Examining properties (gold) for W. A. Carlyle in Dutch East Indies. 1912-13, Manager, Alluvial Tin Co., Nigeria, and Asst. Mgr., Naraguta (Nigeria) Tin Co.

Present position: Manager for one of the Naraguta Co.'s properties in Nigeria.

Paul Weiller, Perth Amboy, N. J.

Proposed by Henry M. Howe (two additional signatures required).

Born, 1885, Trieste, Austria. 1902-06, Technische Hochschule, Vienna (Chemistry). 1906-08, Technische Hochschule, Berlin (Metallurgy). 1907, Degree of Diplom-Ingenieur. 1909, Degree of Dr. Ingenieur, both from Technische Hochschule, Berlin. 1891-95, Instruction at home. 1895-1902, Staatsrealschule, Trieste, Austria. 1909-11, Societa Siderurgica di Savona, Italy, steel work. 1911-12, Ungarische Metallverhuettungsgesellschaft, Fiume, Hungary, lead smelter. 1912-13, Dobsinaer Kupferwerke, Dobsina, Hungary, copper work. 1913, United States Smelting & Refining Co., Chrome, N. J.

Present position: Conducting own laboratory.

W. C. West, Cobalt, Ont., Can.

Proposed by Frank W. Durkee, Alfred C. Lane, Charles F. Rand.

Born, 1879, Concord, N. H. 1897-1901, Tufts College, Mass. Metallurgical Chemistry. 1901-04, Cyanide work in Mexico. 1904-05, Metallurgist with Amparo Mining Co., Jalisco, Mexico. 1905-06, Mgr., Black Peak Gold Mining Co., New Mexico. 1906-08, Supt., La Republica Mining Co., Chihuahua, Mexico. 1908-09, Metallurgist with Dos Cabezas Mining Co., Sonora, Mexico. 1909-11, Gen'l. Mgr., Creston de Oro Mining Co., Sonora, Mexico. 1911-13, Supt., Cornwall Copper Co., Ste. Genevieve, Mo.

Present position: Manager, Peterson Lake Silver Cobalt Mining Co., Cobalt, Ont., Canada.

Robert S. Wheatley, Salineville, Ohio.

Proposed by E. O'Toole, S. B. Belden, J. T. Beard.

Born, 1877, Salineville, Ohio. To 1893, Common and High Schools, Salineville, Ohio. 1907, Preparatory, Carnegie Tech. 1893-1905, Employed in various capacities in and around the mines of the Big Vein Coal Co., Ohio & Pa. Coal Co., and Sterling Mining Co., Cleveland, Ohio. 1906, Mine Boss and Supt. of Sterling mine at Salineville.

Present position: 1910 to date, Mine Inspector, State of Ohio.

Percy Thomas Williams, Seattle, Wash.

Proposed by F. A. Hill, J. Daniels, M. Roberts.

Born, 1882, Rancorn, England. To 1896, Common Schools. 1896-97, Liverpool Institute. 1897-1901, Rancorn Technical Institute; Goldsmith Polytechnic, London. 1901-02, London Univ. Kings College; special course Power Plant Economics. 1903, Manchester Univ.; special course in Geology. 1897-1901, Apprentice to Civil Engineering firm. 1901-02, Sturtevant Eng. Co., London, Eng. 1902-03, Heenan & Froude, Manchester, Eng., Coal Mine Equipment. 1903-04, Sadbury Mines, Copper Cliff and Ontario Gov. Land Survey. 1904-08, Cascade Power Co., Cascade, B. C. 1908-09, Seattle Electric Co., Renton Mine. 1909-13, Wilkeson Coal & Coke Co.

Present position: 1913 to date, Mining Engineer with Pacific Northwest Coal Co.

Oba Wiser, Hayden, Ariz.

Proposed by D. D. Moffat, L. S. Cates, W. S. Boyd.

Born, 1870, Winchester, Kan. To 1883, Common Schools, Winchester, Kan. 1883-84, State Univ. Kan. 1885-87, Teaching public schools, Kansas. 1888-89, Lawrence Business College, Kan. 1890-93, Aspen Foundry & Machine Shops, Aspen, Colo. 1894, Smuggler Mining & Milling Co., Aspen, Colo. 1896-97, Proprietor El Paso Iron Works, Cripple Creek, Colo. 1898-99, Portland Gold Mining Co., Cripple Creek, Colo. 1900, Butte Reduction Works, Butte, Mont. 1901, Consolidated Mercur Mining Co., Mercur, Utah. 1902-05, Annie Laurie Mining Co., Kimberly, Utah. 1906-07, Mgr., White Pine Gold Mining & Milling Co., Warm Springs, Nev. 1908-10, Utah Copper Co., Garfield, Utah. 1911-13, Ray Con. Copper Co., Chino Copper Co., Hurley, N. M. Butte Superior Copper Co., Ltd., Butte, Mont.

Present position: Metallurgical Engineer, Hayden Plant, Ray Consolidated Copper Co.

Merl Ruskin Wolfard, Cambridge, Mass.

Proposed by H. L. Smyth, W. S. Weeks, G. S. Raymer.

Born, 1879, Muncie, Ind. 1904, S. B., Univ. of Wyom. 1910, M. M. E., Harvard Univ. 1911-13, Oil Engine Research at Harvard. 1904, Repair work in copper smelting plant of Penn. Wyoming Copper Co. 1904-05, Machine Shop and Designing Dept., Monitor Drill Co. of Minneapolis, Minn. 1905-06, Asst. night engineer, Tie Treating Plant at Laramie, Wyo., for U. P. R. R. Co. 1906-07, Asst. and Grad. work at Univ. of Wyoming. 1907-08, Instructor in Mech. Engr. at the Univ. of Pa.

Present position: 1910 to date, Instructor in Mech. Engr. at Harvard.

Associates

Talcott Hunt Clarke, Youngstown, O.

Proposed by Thomas T. Read (two additional signatures required).

Born, 1884, Rochester, N. Y. 1901-03, Lawrenceville School, Lawrenceville, N. J. 1903-06, Sheffield Scientific School; Ph. B. Took course Preparatory to Mining Engineering. 1907, Orient Coke Co., Orient, Pa. The Tidewater Coal Co., Levasy, W. Va. 1907-11, H. K. Wick & Co., Inc., Miners and Shippers of Bituminous Coal, Buffalo, N. Y. Elected Secretary of the company in 1910 and still holds that position.

Present position: 1911 to date, Assistant Purchasing Agent, Republic Rubber Co., Youngstown, O.

John William McBride, Spokane, Wash.

Proposed by L. K. Armstrong, J. McD. Porter, E. P. Spalding.

Born, 1871, Kilbourn City, Wis. Common Schools of Kilbourn City. 1892, Normal School, Mankato, Minn. 1892-1913, Operating coal and metal mines.

Present position: Mine Operator.

Leonard Wilson, Salt Lake City, Utah.

Proposed by F. H. Bostwick, C. F. Moore, W. A. Wilson.

Born, 1874, Yorks., England. 1891-94, Leeds Univ., England, General Engineering. 1894-1901, Brush Elec. Eng. Co., England. Construction, installation, and design of machinery. 1901-05, Stanley Co., Pittsfield, Mass. 1905-09, Power & Mining Dept. G. E. Co. at Schenectady, Denver, and Salt Lake. 1909-13, Consulting Engineer practising in Utah. Engaged on work in connection with use of electric power in the mining districts, including mining machinery and hydro-electric power plants.

Present position: Consulting Engineer as above, Wilson & Ott, Salt Lake City, Utah.

Charles R. Wraith, Anaconda, Mont.

Proposed by F. Laist, P. Barker, J. A. Root.

Born, 1887, Stretor, Ill. 1902, Business Course, Grand Junction, Colo. 1903, High School, Grand Junction, Colo. 1904-07, High School, Anaconda, Mont. 1907-11, Colo. School of Mines, Golden, Colo.; E. M. 1911-14, Anaconda Copper Mining Co.

Present position: Chemist, Anaconda Copper Mining Co.

*Junior Members***Henry August Behre**, New Haven, Conn.

Proposed by L. W. Bahney, J. F. McClelland, Thomas T. Read.

Born, 1893, Brooklyn, N. Y. To 1907, Public School, Brooklyn, N. Y. 1907-10, Adelphi Academy, Brooklyn, N. Y. 1910-13, Studied Mining at the Sheffield Scientific School; Ph. B.

Present position: Studying for the degree of Engineer of Mines at Yale University.

John Cornelissen, New York, N. Y.

Proposed by R. Peele, J. F. Kemp, J. F. Magee.

Born, 1891, Amsterdam, Holland. 1899-1910, Public and High Schools, Amsterdam, Holland. 1910, Columbia Univ., New York City.

Present position: Student.

Ying Chieh Kuang, New York, N. Y.

Proposed by J. F. Kemp, R. Peele, C. P. Berkey.

Born, 1887, Canton, China. 1901-03, Canton Christian College, China. 1903-04, Li Shing Industrial & Scientific College, Hong Kong. 1904-07, College Dpt., Pei Yang Univ., China; A. B. 1907-10, Mining and Metallurgical Dept., Pei Yang Univ.; degree Chin-Su in engineering. 1912-13, Grad. student, mining and metallurgy in Columbia Univ.; A. M. 1908, Iron and coal mining and in steel works, Han Yeh-Ping Co., China. 1909, Geology of coal, Western Hills, Pekin, China. 1910, Geology of iron and coal in Shansi, China. 1911, Prospecting work, San Nui, China.

Present position: 1913 to date, Grad. Student in geology and mining.

Raymond Bardeen Ladoo, Cambridge, Mass.

Proposed by W. S. Weeks, G. S. Raymer, C. H. White.

Born, 1893, Ayer, Mass. 1906-10, Leominster High School, Leominster, Mass. 1910-14, Harvard College, A. B. to be taken in June, 1914.

Present position: Student.

Edmund Tuttle Plumb, New Haven, Conn.

Proposed by L. W. Bahney, J. F. McClelland, J. W. Roe.

Born, 1891, Terryville, Conn. 1913, Ph. B., Yale, Sheffield Scientific School.

Present position: Student.

Donald Franklin Schindler, Madison, Wis.

Proposed by E. C. Holden, C. K. Leith, A. N. Winchell.

Born, 1893, Racine, Wis. 1908-11, Newton High School, Newton, Mass. 1911, Wis. Univ.

Present position: Student.

Maurice B. Walters, New Haven, Conn.

Proposed by L. W. Bahney, J. F. McClelland, J. W. Roe.

Born, 1891, Rochester, N. Y. 1909-11, Yale College. 1911-13, Sheffield Scientific School, Yale Univ.; Ph. B. 1912, Lackawanna Steel Co. 1913, Mountain View Mine, Butte, Mont.

Present position: Student.

*Change of Status—Junior Member to Member***A. I. Abrahams**, New York, N. Y.

CHANGES OF ADDRESS OF MEMBERS

The following changes of address of members have been received at the Secretary's office during the month of January, 1914. This list, together with the lists published in *Bulletin* Nos. 76 to 85, April, 1913, to January, 1914, and the foregoing list of new members, therefore, supplements the annual list of members corrected to Mar. 1, 1913, and brings it up to the date of Feb. 1, 1914.

- ADAMS, FRANK D. McGill Univ., Montreal, Canada.
AUSTIN, EDWIN A. Stockton, Cal.
AUSTIN, L. S., Mining and Metallurgical Engineer, Dooly Block, Salt Lake City, Utah.
BALFOUR, J. FORDYCE Naraguta Post Office, Northern Nigeria.
BANKS, HARRY P. 5715 Meridian St., Highland Park, Los Angeles, Cal.
BORCHERT, WALTER O., Supt., The Bertha Mineral Co. Austinville, Va.
BRANDES, J. F. Box 1245, Station K., San Francisco, Cal.
BRINKER, ARTHUR C., c/o The Buena Tierra Mining Co., Ltd.,
Santa Eulalia, Chih., Mexico.
BROWN, H. J. Box 76, Chester, Pa.
BROWN, HARRY H. 2727 Euclid Ave., Cleveland, Ohio.
BROWNE, ARTHUR B. c/o Malleable Iron Fittings Co., Branford, Conn.
CALLAWAY, F. W. Box 168, Juneau, Alaska.
CHALMERS, THOMAS S. c/o Chalmers & Williams, Inc., Chicago Heights, Ill.
CHAPMAN, JAMES E. Callahan, Siskiyou Co., Cal.
CLAGHORN, CLARENCE R. Box 796, Tacoma, Wash.
CLAGHORN, JAMES L. 434 Riverside Drive, New York, N. Y.
CORNELL, ROY L. 1288 W. 23d St., Los Angeles, Cal.
COUSIN, ROBERT. 95 Muirkirk Rd., Catford, London, S. E.
COXE, EDWARD H., Mgr., LaFollette Coal, Iron & Railway Co., LaFollette, Tenn.
CRAFTS, WALTER N. Oberlin, Ohio.
CROCKER, A. L. 626 Plymouth Bldg., Minneapolis, Minn.
CROOK, WELTON J. State School of Mines, Rapid City, S. D.
CULBERT, J. VICTOR. 784 Wellington St., London, Ont., Canada.
DAKIN, FREDERICK H., JR. 110 Sutter St., San Francisco, Cal.
DALTON, MELVIN P. Rooms 1903-5, 74 Broadway, New York, N. Y.
DAVIS, WALTER W., Attorney at Law. Leadville, Colo.
DILWORTH, J. B. 518 Walnut St., Philadelphia, Pa.
DUBOIS, WARREN L. Y. M. C. A. Bldg., 1164 E. Jersey St., Elisabeth, N. J.
DUFOURCOQ, R. G. Montezuma Lead Co., 82 Beaver St., New York City.
EDMONDSON, H. W. 205 W. 106th St., New York, N. Y.
EDWARD, W. S. 2840 Eleventh Ave., East Oakland, Cal.
ESSELSTYN, J. N. 2330 Downing St., Denver, Colo.
FAWCETT, J. H. 4 O'Connell Street, Sydney, Australia.
FOOTE, W. B. 24 Sherrill St., Geneva, N. Y.
FOUCAR, E. L. 512 Folsom St., San Francisco, Cal.
GEIGER, ARTHUR W., Min. Engr. 220 Mills Bldg., San Francisco, Cal.
GIBBS, G. H. 5 Thoresby Ave., Frodingham, England.
GILHAM, R. E. Townsend, Mont.
GILLET, LORENZO M. 38 West 11th St., New York, N. Y.
GOODCHILD, WILLIAM H. Finsbury Pavement House, London, E. C.
GRAVES, McDOWELL. Lambs Club, Helena, Mont.
GREENSFELDER, N. S. c/o Tacoma Smelting Co., Tacoma, Wash.
GUESS, H. A. 165 Broadway, New York, N. Y.
HAMFELDT, GEORGE K. Oxelösund, Sweden.
HAMILTON, H. T. Moctezuma Copper Co., Nacozari, Son., Mexico.
HAMILTON, J. P. c/o Power & Mining Machinery Co., Cudahy, Wis.
HART, VERNE A. Hotel Plandome, Box 1003, Salt Lake City, Utah.
HENDERSON, H. P. 66 Broadway, New York, N. Y.
HERZIG, C. S., Consulting Mining Engineer, 1 London Wall Building, London, E. C.
HONEYMAN, E. W. c/o St. Francis Apartment Hotel, Eugene, Ore.
HYSLOP, JAMES E. 1739 Sycamore Ave., Hollywood, Los Angeles, Cal.
JACKLING, DANIEL C. Box 1775, Salt Lake City, Utah.
JARVIS, R. P. Box 1039, Knoxville, Tenn.
JENNINGS, ROBERT E. Carpenter Steel Co., 100 Broadway, New York, N. Y.
JONES, EVAN ROSSER. Eagle Pass, Texas.
JONES, L. W. 616 East Montgomery Ave., Bryn Mawr, Pa.
KENT, WILLIAM. 120 West 32d St., New York, N. Y.
KENTON, P. Brookfield, Curvier Lane, Ashton-on-Lyne, England.
LANDFIELD, J. B. 2520 Gough St., San Francisco, Cal.
LEMMON, DAVID, Mine Manager. Bull Valley Gold Mines Co., Gunlock, Utah.
LEONARD, HARRY R. 1729 North Sixth St., Harrisburg, Pa.
LIDDELL, T. PARKER. Midas, Nev.
LINDAU, S. PAUL, Mining Engineer. c/o Ray Cons. Copper Co., Ray, Ariz.
LONG, JAMES I. 1415 Manhattan Place, Los Angeles, Cal.

MCCARTHY, JOHN EUGENE, Min. Engr.	Lake City, Colo.
McCLINTOCK, WM. H.	401 First St., Healdsburg, Cal.
McKECHNIC, B. E.	Penn. Steel Co., Lebanon, Pa.
MACCARTHY, MARION S.	730 First National Bank Bldg., Denver, Colo.
MACDONALD, J. J.	Sierra Madre Club, Los Angeles, Cal.
MACFEE, ROBERT, The So. Urals Mining & Smelting Co., Tanalyk Baimak, Orenburg Govt., Russia.	
MARTIN, ROBERT L., Jr.	Eugene, Mingo Co., W. Va.
MOORE, L. D.	Chatham, N. J.
MORLEY, FREDERICK H.	2616 Channing Way, Berkeley, Cal.
MUIR, T. K.	Room 412, 57 Post St., San Francisco, Cal.
MUNGER, CHARLES H.	700 Lonsdale Bldg., Duluth, Minn.
NAHL, A. C.	2425 College Ave., Berkeley, Cal.
NATHING, F. S.	118 Fulton St., New York, N. Y.
NOTMAN, ARTHUR	c/o Old Dominion Mining & Smelting Co., Globe, Ariz.
OBBERG, ANTON C., Cons. Min. Engr.	503 Manhattan Bldg., Duluth, Minn.
PAGE, WILLIAM N.	1863 Kalerama Road, Washington, D. C.
PALMER, I. A.	Baldwin, Pa.
PERRY, EDWARD HALE, Geol.	135 Beacon St., Boston, Mass.
RICE, E. ROCHE	Box 2286, Bisbee, Ariz.
ROBE, LLOYD A.	Apartado 333, Torreon, Coah., Mexico.
ROPP, ALFRED VON DER.	233 Broadway, New York, N. Y.
RULE, J. A.	c/o International Smelting & Refining Co., Tooele, Utah.
SANDERSON, H. S.	326 Century Bldg., Denver, Colo.
SAWYER, A. H., Min. Engr.	412 American Trust Bldg., Birmingham, Ala.
SCOTT, WALTER PRESTON	804 Washington St., Moscow, Idaho.
SEDGWICK, ALLAN E.	216 Central Bldg., Los Angeles, Cal.
SELKIRK, W.	3 London Wall Buildings, London Wall, London, E. C., England.
SESSINGHAUS, GUSTAVUS, Min. Engr.	728 Foster Building, Denver, Colo.
SMITH, BERT F.	804 Washington St., Moscow, Idaho.
SMITH, GEORGE OTIS	U. S. Geological Survey, Washington, D. C.
SMITH, J. WILLIAM	1615 West Genesee St., Syracuse, N. Y.
SOHNLEIN, MAXIMILIAN GEORGE FERDINAND, Min. Engr., c/o Cia. Minera de Oruro, Ingenio de Machacamara, Bolivia, S. A.	
STEHLI, H. J., Met. Engr., Supt., Dwight & Lloyd Sintering Co.,	29 Broadway, New York, N. Y.
TALCOTT, M. GARDNER	121 So. Broadway, Irvington on Hudson, N. Y.
TAYLOR, JAMES	Greenleaf, Brierley St., Mosman, N. S. W., Australia.
THOMSON, HENRY N.	211 South Sixth East, Salt Lake City, Utah.
TIBBY, BENJAMIN F., Min. Engr.	420 Judge Bldg., Salt Lake City, Utah.
TOM, I.	Box 2951, Johannesburg, Transvaal, So. Africa.
TUCKER, A. W., Cons. Min. Engr.	Box 374, Salisbury, N. C.
VAN MATER, J. A.	21 Myrtle Ave., Plainfield, N. J.
WARD, ERNEST E.	Anyox, B. C., Canada.
WARREN, FRANK M.	3443 South Irving Ave., Minneapolis, Minn.
WARTENWEILER, FRED	Box 1056, Johannesburg, Transvaal, So. Africa.
WATT, A. P.	St. Francois, Miss.
WHEELER, A. E., c/o Robert Williams & Co.,	Friars House, New Broad St., London, E. C., England.
WILKINSON, C. D., Min. Engr.	20 Copthall Ave., London, E. C., England.
WILSON, A. M.	Nucila, Colo.
WILSON, J. BOWIE, Wentworth Court, Elizabeth St., Sydney, N. S. W., Australia.	
WOLFLIN, H. M., Industrial Accident Commission, Underwood Bldg.,	525 Market St., San Francisco, Cal.
WOOD, C. L.	522 Platt St., Toledo, Ohio.
WORKMAN, CHARLES	R. R. 3, St. Catharines, Ont., Canada.
WRIGHT, LOUIS A.	1001 North Campbell St., El Paso, Texas.

ADDRESSES OF MEMBERS AND ASSOCIATES WANTED

Name.	Last Address of Record, from which Mail has been Returned.
Grill, Charles H.,	Keddie, Cal.
Grove, Independence,	Ampiro Mining Co., Etsatlan, Jal., Mexico.
Hyslop, James E.,	Apartado 48, Parral, Chih., Mexico.
Johnson, Alexander T.,	Yellow Pine Mining Co., Good Springs, Nev.

Keller, Cornelius H.,	Apartment 134, Parral, Chih., Mexico.
Lancaster, Henry M.,	Coeur d'Alene, Idaho.
Lehmer, Frank W.,	Cia Minera Zapoteca, Ocotlan, Oax., Mexico.
Linton, R. A.,	Saginaw, Mich.
Potter, Charles F.,	First National Bldg., San Francisco, Cal.
Schroder, Harold,	Eng. & Aust. Cop. Co., Wasatah, Tasmania.
Terrie, Josiah H.,	Calaveras Copper Co., Copperopolis, Cal.
Watters, Daniel M.,	2557 11th Ave. W., Seattle, Wash.

NECROLOGY

The deaths of the following members were reported to the Secretary's office during the month of January, 1914:

Date of Election.	Name.	Date of Decease.
1877	*Billings, George H.	December 31, 1913.
1881	*Cummings, George P.	
1904	*Hallett, S. I.	September 14, 1913.
	*Member.	

BIOGRAPHICAL NOTICES

Jesse Everett Dwelle was born Jan. 18, 1875, in St. Louis, Mo., and removed to Denver in August, 1875, at the age of six months. He received his early education in the public schools of Denver, leaving the East Denver High School at the end of the third year to enter the School of Mines at Golden, Colo., where he was graduated with the class of 1896. In the fall of 1895 he became associated with the *Colliery Engineer*, and later with the International Correspondence Schools, at Scranton, Pa., where he remained until 1898, when he went to Costa Rica for the Bella Vista Mining & Milling Co. He remained in charge of this company's cyanide mill as Superintendent for two years. In 1890 he became Superintendent of the reduction plants of the Inca Mining Co., operating in Peru, in which capacity he served for two years, returning to the United States in 1902. For the next six years he was engaged in the general practice of mining engineering, making special examinations in the United States, Mexico, and Peru. In 1908, he became associated with the Empire Zinc Co., and continued with them as an engineer up to the time of his death, at Tucson, Ariz., Nov. 18, 1913.

Besides this Institute, which he joined in 1898, Mr. Dwelle was a member of the American Society of Mining Engineers, the Alumni of the School of Mines of Colorado, the Colorado Scientific Society, and the National Geographical Society.

John S. Fackenthal was born Oct. 14, 1862, at Durham, Bucks county, Pa. His father, Benjamin F. Fackenthal, was an eminent lawyer of Easton, Pa., and for some years Manager of the Durham Iron Works. He himself, after graduating from the Easton High School and attending for a year the Pardee Scientific School of Lafayette College, entered the Durham works, which had become the property of Cooper & Hewitt, and of which his elder brother, B. F. Fackenthal, Jr., was in charge. Here he learned the manufacture of pig iron; and in 1886, at the age of 24, he was made Superintendent of the firm's Pequest Iron Works, in Warren county, N. J. Rising rapidly in reputation as an expert, he

was employed in 1889 by a New York syndicate to report on the iron industries and resources of Alabama, Georgia, and Tennessee; and after finishing this work, he was appointed Superintendent of the Glendon Iron Works, near Easton. While occupying this position he was elected a member of the School Board of that city, on which he served with conspicuous ability and fidelity for six years, during two of which he was President. In 1903, he was made General Manager of the Consolidated Lake Superior Co., a corporation of \$100,000,000 capital and diversified industries, which had become financially embarrassed; and in that capacity he aided his brother, B. F. Fackenthal, Jr., who was administering the company's affairs as receiver, and whose skillful management saved the enterprise from destruction and put it upon a safe footing. At the time of his death, Oct. 13, 1913, he was Secretary of the Clymer Power Co., which operates a hydro-electric plant at Raubsville, Pa., near Easton. He died of cancer in the throat, after prolonged suffering borne with characteristic fortitude, and only temporarily relieved by surgical means.

Mr. Fackenthal became a member of the Institute in 1887.

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ROBERT H. RICHARDS,
HEINRICH RIES,
E. F. ROEBER,
RENO H. SALES,
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CHARLES H. SHAMEL,
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¹ Until Feb., 1914. ² Until Feb., 1915. ³ Until Feb., 1916. ⁴ Until Feb., 1917.

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	Parts
SiO ₂	10.8
Fe ₂ O ₃ Al ₂ O ₃	6.8
CaO.....	41.4
MgO.....	Trace
SO ₃	8.0
Cl.....	8.0
Organic and volatile.....	2.0
Total.....	77.0

Experiments on cyanide consumption by the arroyo water showed that after six hours' contact a quantity of cyanide had been consumed equivalent to 0.44 lb. KCy per ton of water, which was reduced to 0.11 lb. KCy per ton of water when alkali was added. A branch of the main arroyo flowing into it at the mill carries pure water, which did not attack the cyanide. The tests were made when the stream was at a low stage and the water naturally carried more impurities than would be the case during the greater part of the year.

The supply of lime heretofore available is quite impure, but contains nothing prejudicial to cyaniding. The analysis of an average sample of burned lime is as follows:

	Per cent.
SiO ₂	8.8
CaO.....	54.8
MgO.....	4.5
Fe ₂ O ₃	1.9
Al ₂ O ₃	3.2
CO ₂	13.9
H ₂ O.....	12.2
Total.....	99.3

Of this lime, 50 lb. digested for 6 hr. with a ton of standard KCy solution showed no cyanide consumption; hence the material could be used. After considerable search, however, a better grade of lime has been found, which can be obtained at a slightly higher cost.

Recasting the analysis of an average sample of battery heads for one month, and the analysis of the lime, water, and cyanide used, we find the chemical composition of the consolidated mill charge, as given below. In this month 40 lb. of lime was used per ton of ore; the ratio of solution to ore was 6 : 1; the strength of solution, 0.23 per cent., 120 parts of sodium cyanide being used to 100 of ore. The solids in the charge per ton of ore milled would be made up approximately as follows:

	Pounds		Pounds
Insoluble.....	1,755.29	CN.....	14.63
Fe.....	55.00	As.....	0.10
Fe ₂ O ₃	1.00	CO ₂	77.70
Fe ₂ O ₄		S.....	33.60
Al ₂ O ₃	24.87	SO ₃	0.08
CaO.....	114.41	Cl.....	0.08
MgO.....	0.80	Au.....	0.025
Cu.....	0.20	Ag.....	1.44
MnO ₂	10.00	Volatile }	0.09
Na.....	12.97	Organic }	

Special Tests on Small Samples

A model Pachuca tank 10 in. in diameter by 30 in. high and connected with small zinc-boxes was rigged up for experimental work. From 25- to 50-lb. samples were treated in this, and the details of treatment were worked out here and subsequently checked by agitation of 20-ton charges in the cyanide plant. The ore was ground to 120-, 150-, and 200-mesh; solutions of different strengths were used; and the various conditions influencing the treatment were thoroughly tested. Without going into the numerous details, the results may be summarized as follows:

It was not possible to obtain nearly as high extraction with pulp ground to 120- or 150-mesh as with that ground to 200-mesh—demonstrating the necessity of fine grinding.

The strength of solution most favorable for the treatment of this ore is about 0.32 per cent. KCy. Weaker solutions can be used to obtain equally high extraction if the time of treatment be increased. With this strength of solution the period of agitation necessary for extraction percentage as given below was 34 hr.

Protective alkalinity should be maintained during agitation up to 0.08.

The use of lead acetate was found to be of no benefit in connection with the treatment.

With the treatment as outlined above, the consumption of cyanide averaged about 1.4 lb. and that of lime about 12 lb. per ton of ore treated. These are the actual amounts of materials destroyed by the reactions of the process. Including mechanical losses, there would probably be in a working plant a consumption of about 2.5 lb. of 98 per cent. potassium cyanide, and 15 to 20 lb. of lime per ton of ore treated.

The extraction of silver from samples ground to 200-mesh varied from 84 to 89 per cent.; the gold extraction from 93 to 95 per cent. A recovery of 85 per cent. should be effected in operating.

Cyaniding Concentrates

A series of tests was also made on cyaniding the concentrates. The writer has already given details of these in a previous paper.³ The results indicated that the most economical treatment was to grind the concentrates in 0.2 per cent. KCy solution, and agitate in a 0.6 KCy per cent. solution which was raised to 0.8 per cent. toward the end of the treatment, the protective alkalinity being maintained at 0.10. The use of lead acetate did not benefit the extraction; but a small amount assisted in keeping the solutions clear. In treating ore of ordinary grade, there is no benefit to be derived from concentrating. It may be of advantage in handling the rich ore from bonanza shoots such as appear to be characteristic of the ore occurrence here, having been encountered from time to time in the past. In the new mill, concentrating equipment is not provided, but the mill is so designed that this can be added when needed.

The New Mill

After the metallurgical details had been worked out a new cyanide mill was designed, which follows closely the outline of treatment derived from this preliminary work. The site selected was El Salto, where the old cyanide mill was located, since it is the most favorable as regards both the contour of the ground, and transportation of ore from the mines. The machinery for the first unit of this mill was ordered and construction work had been begun when it was decided to suspend operations until political conditions in Mexico should become more settled. The equipment for this first unit consists of the following:

One 20- by 10-in. Armour cast-steel Blake Marsden type rock breaker.

One battery of ten 1500-lb. stamps, with open-front mortars, fluted cam shaft, Blanton cams, individual El Oro guides, Nelson suspended automatic feeders.

One Newago screen.

Two 4 by 20 tube mills, roller bearing on discharge end, trunnion bearing on feed end, connected by single reduction gear to special type I 24 General Electric high-torque motors.

One Esperanza type classifier, 20 ft. 7 in. by 4 ft. by 3 ft. 8 in. maximum depth.

One 40- by 16-ft. Dorr thickener, with tank.

One 35- by 12-ft. Dorr thickener, with tank.

Three standard 15- by 45-ft. Pachuca agitators.

One 10- by 12-ft. tank with mechanical agitator.

One Oliver continuous slime filter, 125 tons capacity per 24 hr.

One Gwynne solution multistage centrifugal volute turbine pump, capacity 250 gal. per minute against 150 ft. head.

³ *Journal of the Chemical, Metallurgical and Mining Society of South Africa*, vol. xiii, No. 1, p. 14 (July, 1912).

Two 4-in. Gwynne centrifugal slime pumps.

One 10- by 12-ft. slime receiving tank.

One 35- by 16-ft. main solution tank.

Two 16- by 10-ft. pregnant solution tanks with clarifying sand filters.

Two 20- by 14-ft. sump tanks.

Two double-column zinc-boxes.

One 5- by 5- by 6-ft. clean-up tank.

One S. H. Johnson precipitate press.

One tilting furnace of the Butters type, for No. 400 crucible.

One Hampton zinc lathe.

The rock breaker, stamp mill, and tube mills are manufactured by the English firm of Fraser and Chalmers.

The compressor to furnish air for the Pachuca agitators, and some other minor items, will be furnished from equipment previously on hand.

Outline of Treatment

The ore from the mines is received in a small bin above the rock breaker, and crushed in the latter to 2-in. size. It is then delivered by a belt conveyor to a Newago screen above the battery ore bins which constitute the main storage. Material coarser than $\frac{3}{16}$ in. goes to the battery bins and the fines go to a separate bin at one end. The fines are delivered by a belt conveyor directly to the classifier. The over-size is crushed in the battery to 5-mesh and passes to the classifier. The classifier is set between the two tube mills and receives the tube-mill discharge as well as the battery pulp, constituting a closed circuit with constant overflow of slimes. It is estimated that the ratio of solution to ore in the tube-mill feed will be 6 to 1.

The overflowing slime is pumped to the primary thickener, where it is thickened to a 2 to 1 consistency, the overflowing solution being returned directly to the battery. The thickened pulp flows to the Pachuca agitators, which are connected in series for continuous agitation. Cyanide is dissolved in a small tank above the agitators, and added to the slime as required to maintain the solution at proper strength. At the estimated capacity of the mill the pulp would require 55 hr. to make the circuit of the tanks. The surplus agitator capacity is to provide against loss of values by a portion of the slime passing from one tank to the next before it is thoroughly agitated, and to prevent cutting down the capacity of the mill when a tank has to be put out of service temporarily, as for instance through accumulation of slime on the bottom. The arrangement is such that any tank can be thrown out of the circuit and the slime by-passed.

From the Pachucas the slime passes to the secondary thickener, where the ratio of solution to dry slime is reduced to 1.5 to 1. It then passes to

the mechanical agitator, and barren solution of the lowest grade available is added and the whole thoroughly agitated, effecting a preliminary washing and dilution. It is then filtered in the Oliver filter and the residues are washed and discharged. It is estimated that these residues will carry 30 per cent. solution, to make up for which and for evaporation will probably permit the use of a quantity of wash water equivalent to 60 to 70 per cent. of the tonnage of ore milled.

The overflowing solution from the secondary thickener and the solution from the Oliver filter flow to the clarifying sand filters, thence to the zinc-boxes and barren-solution sumps. The barren solution is pumped to the mill-solution tank above the battery.

The designing of the mill and selection of equipment has kept in view the larger capacity that will probably be required ultimately. Units of the same capacity as this first one can be added as rapidly as needed without any interruption in operating at the existing capacity.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the New York meeting, February, 1914, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Apr. 1, 1914. Any discussion offered thereafter should preferably be in the form of a new paper.

Notes on Conservation of Lake Superior Iron Ores¹

BY C. K. LEITH, MADISON, WIS.

(New York Meeting, February, 1914)

THE questions as to what grades of ore it pays to conserve for the future, and the valuation of low-grade reserves, are becoming immediate and definite as applied to individual ore deposits, and seem to call for some sort of quantitative answer. Both opinion and practice involving these questions differ widely. The number of variables in this problem is so large that final solution will perhaps never be agreed upon, yet there seem to me to be certain controlling factors which can be placed in quantitative relation and serve to reduce the number of variables which it is necessary to consider in a given instance.

I assume that it will not pay either for the individual or for the State to conserve any ore when the present cost of conservation (by stock piling or otherwise), when compounded at 6 per cent. interest for the number of years which would elapse before this ore is used, will exceed the profit which the ore will yield when it is used. It may be urged that any loss to the individual may be made up in gain to the State. This might be true if there was any definite limit to the amount of iron ore, but when we remember that iron makes up 4 per cent. of all the rocks of the earth and the amount of rock carrying iron in excess of 20 per cent. is, for practical purposes, unlimited, it is apparent that posterity is assured of its iron ore. The changes will be mainly in methods and cost of extracting the ore. Therefore, any expenditure of money or effort now, which when compounded will exceed the worth of the effort or money needed in the future to utilize the iron, is a net loss both to the individual and to the community.

On the accompanying plate, Fig. 1, prepared by W. J. Mead, the amount of any given sum compounded at 6 per cent. interest for a given

¹The subject of the economic possibilities of conservation is approached by the economists from a point of view which is perhaps new to some mining men. The reader may be interested in two short general papers on the subject, entitled:

Some Economic Aspects of Conservation, by Ralph Henry Hess, *Original Communications to the Eighth International Congress of Applied Chemistry*, vol. xxvi, p. 711 (1912).

The Economic Possibilities of Conservation, by L. C. Grey, *Quarterly Journal of Economics*, vol. xii (May, 1913).

period up to 40 years may be read. For instance, if it cost 10c. a ton to conserve ore, at the end of 20 years this amount will be 32c.

The present cost can be easily determined. Both the time at which an ore will be used and the future profit are matters of speculation, but I believe it is possible to set certain limits for them.

Future Profits.—Just as ores now show the widest variety of availability, depending on chemical and mineralogical composition, texture, geologic and geographic position, cost of mining, etc., so the ores of lower grade which will be used in the future will show like variation in availability. The only factor common to all ores which can be used to summarize and compare the different ores is profit per ton. Profit determines whether a given ore can now be used and will determine this in the future. If, therefore, we can approximate the profit per ton for any given ore, at any given time in the future, we can easily calculate how much, if anything, one can afford to spend now to save this ore. This profit can never be accurately predicted in advance, but I believe it may have much the same relation to values of higher-grade ores as it has at present. If a 50 per cent. ore now shows a mining profit of \$1.50 per ton, the lower grades as calculated from penalties will show profits of a fraction of this amount, ranging down to zero. In certain favored Lake Superior localities 38 to 40 per cent. low-phosphorus, high-silica ore can be mined now at a profit of 25c. or less. In less favored localities, where now only the higher-grade ores are being mined, the time will come when the lower-grade ores will necessarily be mined; but when this time arrives, the profit per ton will probably be at least as low as the present profit for such low-grade ores mined from the most-favored localities and as low as the price we now figure from penalties, for the tonnage of the lower-grade ore available is so vast and so widely distributed that its extraction will be necessarily accomplished on a small margin of profit, like a manufacturing enterprise, such as, for instance, the utilization of clay and cement materials. The total cost to the consumer may be the same, but relatively more of the cost will go to fuel and to handling the larger quantities of material necessary to produce a given unit of finished product.

More specifically, I cannot see that there is any basis for hope that 40 per cent. Mesabi ores will be mined at any more profit per ton than the Marquette low-grade ores. When these 40 per cent. Mesabi ores come to be mined they will be in competition with enormous quantities of 40 per cent. ores elsewhere, and they will be mined at a very low margin.

Time.—For any given iron-ore district, the rate of exhaustion of the higher-grade reserves may be roughly figured and the time estimated in which the successively lower grades are likely to come into use. For instance, the average percentage of iron in the Lake Superior ores has been showing during the past decade a drop of about a third of 1 per cent. per year. With a present average of about 49 per cent. natural, at the present

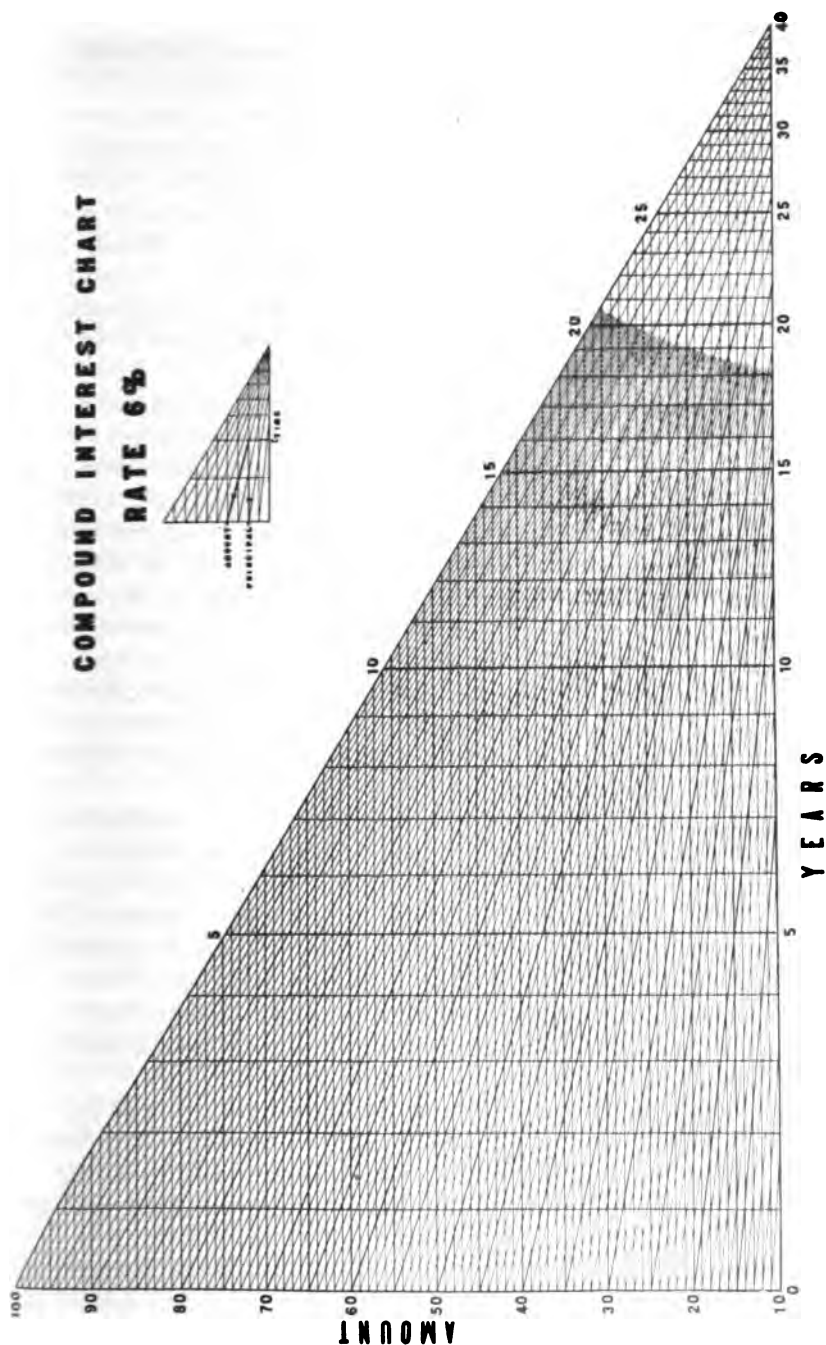


Fig. 1.—CHART FOR DETERMINING COMPOUND INTEREST AT 6 PER CENT. FOR ANY PERIOD BETWEEN 1 AND 40 YEARS.

rate of decrease of grade a 45 per cent. ore would come to be used in about 12 years. This time, of course, would not be uniform for all districts. Certain ores will be used long before others. This is a minimum time, because we must remember that as the grade falls the tonnage of available ores is enormously larger, which will slow up the rate of the decrease of grade. Also it is to be remembered that really only a small portion of Lake Superior is thoroughly explored. I suspect that, outside of the Mesabi, for a hundred years to come high-grade reserves will be added to more or less in proportion to the expenditure made in exploration. Finally, there is the probability of effective competition of foreign ores. I should say, roughly, that in any given district, one would need to be optimistic to predict the use of an average grade 5 per cent. lower than the present prevailing grade in a period shorter than 30 years.

Interpretation of Chart.—With these facts in mind, let us assume that it costs now 25c. per ton to conserve an ore which is 5 points lower than the present commercial grade. Let us also take an optimistic view of the situation and say that this lower grade when mined is going to yield a profit of 50c. a ton, which is certainly better than anything that could be figured out from the present profits on such ores, or from the calculation of penalties. It is apparent from the chart that such an ore must be used in 12 years unless there is to be a loss on the money invested in conserving the ore. If, on the other hand, it costs only 10c. per ton to conserve this ore, and the profit is assumed to be 50c. per ton in the future, it would be possible to hold the ore 28 years. If the profit per ton is assumed to be 25c. and the present cost of conserving it is 5c., it is possible to hold it for 28 years.

Without going into further illustrations, and without arguing for any specific figures of time and profit, it seems clear that there is a narrow limit to the sums which it is wise to spend to conserve low-grade ores. It is my opinion that 25c. per ton profit at a period over 30 years away may be the condition of mining the greater part of the ores 5 points lower than the present standard for any locality. It is apparent that it would pay to spend a very few cents a ton to conserve these ores. If this is true, the present value per ton in the ground of such low-grade ores is practically negligible.

In the above discussion royalty is included as a profit. The payment of royalty to the fee owner by the lease holder amounts to a division of profit. The profit of either party would, therefore, be lower than the figures I have given. It follows that royalties on low-grade ore will need to be pretty low.

The above suggestions are offered tentatively in the hope that they may bring out some discussion.

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The American Steel-Rail Situation

BY ROBERT W. HUNT, CHICAGO, ILL.

(New York Meeting, February, 1914)

ONE of the most serious and important economic administrative problems facing American railway authorities to-day is that of their rails, and it is one to which much thought is being given, not only by the executive officers of the railways and the manufacturers of the steel rails, but also by State and National commissions. It is realized by many and admitted by some that the present situation is one which cannot continue. The roadways of railways must be made more secure, or the weight of rolling stock and the speed of trains must be lessened; and the desired result must be attained with the minimum outlay of money, both in expenditure on plant and in cost of operation. If the investment per mile is too large, or through the lessening of tonnage and efficiency of equipment the cost of operation is too great, the desired and demanded cheap service cannot be rendered to the public. Therefore, the weight of equipment cannot be greatly reduced, and lessening the rapidity of service would be far from satisfactory; consequently, the safety of the roadway must be secured with the least practical outlay.

It is imperative that the roadbed should be properly graded, with the fewest practically possible curves; that it should have good ballast, be well drained, have good ties properly spaced, and be laid with sound rails of suitable weight, efficiently joined together, and that the whole property be carefully and intelligently cared for.

My province is to treat of the sound rails.

During the last few years there has been renewed interest in and discussion of that question, and I know that many rail makers not only have been and are desirous of maintaining the highest standards of manufacture which they may have attained, but have been and are seeking to better their product, in several instances devoting much time and money to that end. At the same time, they realize that the cost of any improvement in quality which they may accomplish must be kept within certain commercial bounds; and that fact is as fully understood by their patrons as by themselves, and it should be kept in mind by all who discuss the question.

As a matter of record, I present in Fig. 1 a summarized statement of

what may be called the mechanical practice of the steel-rail mills of the United States and Canada.

It will be noted that the several works differ in their practice as to kind of steel, size of heats, size of ingots, kind of blooming and rail trains, number of passes in the rolls of both trains, and as to direct rolling into rails; also as to the details of the finishing departments of the several mills. In consequence of such variations, there are, of course, differences in the operating practice of the several plants. One thing that, in my judgment, has had a great effect upon the quality of the product of all the mills is that the workmen have been and are paid on a tonnage or piece basis, with, in some cases, an additional prospective bonus based on quantity of product. Unfortunately, after the produced rails had left the works, there was but little chance of the identity or individuality of the workmen in the different departments of the works, who made them, being connected with them. It is true that a number corresponding with that of the heat of steel from which they had been rolled, and the month and year in which they were made, and the name of the works, were branded on each rail, but to actually identify the steel maker who made the steel, the heater who heated it, the roller who rolled it, the shearman who cropped the blooms, etc., would have been a complicated and practically impossible proposition. One result was that if, for any reason, such as delays from accidents to machinery, etc., the quantity of product was threatened, there was temptation to in some way cut corners, the workmen knowing that if the rails were once out of the mill they need not worry over any individual responsibility, which feeling was simply human.

In an endeavor to meet this and other phases of the situation, some two years ago I ventured the establishment of a system of more constant and thorough inspection of rail making than had been generally, if at all, practised. In this movement I received the support at first of several and later of many of the railroad companies of this continent, and I am happy to say that I have also received the loyal support of the officials of the several steel companies. This system of inspection I explained in a former paper, presented at the Cleveland meeting, October, 1912.¹

I have repeatedly shown that without sound ingots there will not be any certainty of producing sound rails; and that, as each ingot is an individual steel casting, some means should be adopted of testing for soundness the rails produced from each ingot; and until reliable ways of casting sound ingots are adopted the importance of such testing should not be overlooked or underestimated. It is possible to make sound ingots. It will cost more than the present practices; but is that a good argument against it? Whether that increased cost should be added to the selling

¹ Recent Developments in the Inspection of Steel Rails, *Bulletin* No. 72, Dec., 1912, pp. 1487 to 1495.

AMERICAN STEEL RAIL MILL PRACTICE										OCTOBER 19 1913										COMPILED BY ROBT. W. HUNT & CO. CHICAGO, ILL.										c. w. Jones, Jr.										NOTES																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
NAME OF COMPANY	NAME OF MILLS	LOCATION	NO. OF RAILS PRODUCED IN 1913	MADE IN 1913	MADE IN 1912	MADE IN 1911	MADE IN 1910	MADE IN 1909	MADE IN 1908	MADE IN 1907	MADE IN 1906	MADE IN 1905	MADE IN 1904	MADE IN 1903	MADE IN 1902	MADE IN 1901	MADE IN 1900	MADE IN 1899	MADE IN 1898	MADE IN 1897	MADE IN 1896	MADE IN 1895	MADE IN 1894	MADE IN 1893	MADE IN 1892	MADE IN 1891	MADE IN 1890	MADE IN 1889	MADE IN 1888	MADE IN 1887	MADE IN 1886	MADE IN 1885	MADE IN 1884	MADE IN 1883	MADE IN 1882	MADE IN 1881	MADE IN 1880	MADE IN 1879	MADE IN 1878	MADE IN 1877	MADE IN 1876	MADE IN 1875	MADE IN 1874	MADE IN 1873	MADE IN 1872	MADE IN 1871	MADE IN 1870	MADE IN 1869	MADE IN 1868	MADE IN 1867	MADE IN 1866	MADE IN 1865	MADE IN 1864	MADE IN 1863	MADE IN 1862	MADE IN 1861	MADE IN 1860	MADE IN 1859	MADE IN 1858	MADE IN 1857	MADE IN 1856	MADE IN 1855	MADE IN 1854	MADE IN 1853	MADE IN 1852	MADE IN 1851	MADE IN 1850	MADE IN 1849	MADE IN 1848	MADE IN 1847	MADE IN 1846	MADE IN 1845	MADE IN 1844	MADE IN 1843	MADE IN 1842	MADE IN 1841	MADE IN 1840	MADE IN 1839	MADE IN 1838	MADE IN 1837	MADE IN 1836	MADE IN 1835	MADE IN 1834	MADE IN 1833	MADE IN 1832	MADE IN 1831	MADE IN 1830	MADE IN 1829	MADE IN 1828	MADE IN 1827	MADE IN 1826	MADE IN 1825	MADE IN 1824	MADE IN 1823	MADE IN 1822	MADE IN 1821	MADE IN 1820	MADE IN 1819	MADE IN 1818	MADE IN 1817	MADE IN 1816	MADE IN 1815	MADE IN 1814	MADE IN 1813	MADE IN 1812	MADE IN 1811	MADE IN 1810	MADE IN 1809	MADE IN 1808	MADE IN 1807	MADE IN 1806	MADE IN 1805	MADE IN 1804	MADE IN 1803	MADE IN 1802	MADE IN 1801	MADE IN 1800	MADE IN 1799	MADE IN 1798	MADE IN 1797	MADE IN 1796	MADE IN 1795	MADE IN 1794	MADE IN 1793	MADE IN 1792	MADE IN 1791	MADE IN 1790	MADE IN 1789	MADE IN 1788	MADE IN 1787	MADE IN 1786	MADE IN 1785	MADE IN 1784	MADE IN 1783	MADE IN 1782	MADE IN 1781	MADE IN 1780	MADE IN 1779	MADE IN 1778	MADE IN 1777	MADE IN 1776	MADE IN 1775	MADE IN 1774	MADE IN 1773	MADE IN 1772	MADE IN 1771	MADE IN 1770	MADE IN 1769	MADE IN 1768	MADE IN 1767	MADE IN 1766	MADE IN 1765	MADE IN 1764	MADE IN 1763	MADE IN 1762	MADE IN 1761	MADE IN 1760	MADE IN 1759	MADE IN 1758	MADE IN 1757	MADE IN 1756	MADE IN 1755	MADE IN 1754	MADE IN 1753	MADE IN 1752	MADE IN 1751	MADE IN 1750	MADE IN 1749	MADE IN 1748	MADE IN 1747	MADE IN 1746	MADE IN 1745	MADE IN 1744	MADE IN 1743	MADE IN 1742	MADE IN 1741	MADE IN 1740	MADE IN 1739	MADE IN 1738	MADE IN 1737	MADE IN 1736	MADE IN 1735	MADE IN 1734	MADE IN 1733	MADE IN 1732	MADE IN 1731	MADE IN 1730	MADE IN 1729	MADE IN 1728	MADE IN 1727	MADE IN 1726	MADE IN 1725	MADE IN 1724	MADE IN 1723	MADE IN 1722	MADE IN 1721	MADE IN 1720	MADE IN 1719	MADE IN 1718	MADE IN 1717	MADE IN 1716	MADE IN 1715	MADE IN 1714	MADE IN 1713	MADE IN 1712	MADE IN 1711	MADE IN 1710	MADE IN 1709	MADE IN 1708	MADE IN 1707	MADE IN 1706	MADE IN 1705	MADE IN 1704	MADE IN 1703	MADE IN 1702	MADE IN 1701	MADE IN 1700	MADE IN 1699	MADE IN 1698	MADE IN 1697	MADE IN 1696	MADE IN 1695	MADE IN 1694	MADE IN 1693	MADE IN 1692	MADE IN 1691	MADE IN 1690	MADE IN 1689	MADE IN 1688	MADE IN 1687	MADE IN 1686	MADE IN 1685	MADE IN 1684	MADE IN 1683	MADE IN 1682	MADE IN 1681	MADE IN 1680	MADE IN 1679	MADE IN 1678	MADE IN 1677	MADE IN 1676	MADE IN 1675	MADE IN 1674	MADE IN 1673	MADE IN 1672	MADE IN 1671	MADE IN 1670	MADE IN 1669	MADE IN 1668	MADE IN 1667	MADE IN 1666	MADE IN 1665	MADE IN 1664	MADE IN 1663	MADE IN 1662	MADE IN 1661	MADE IN 1660	MADE IN 1659	MADE IN 1658	MADE IN 1657	MADE IN 1656	MADE IN 1655	MADE IN 1654	MADE IN 1653	MADE IN 1652	MADE IN 1651	MADE IN 1650	MADE IN 1649	MADE IN 1648	MADE IN 1647	MADE IN 1646	MADE IN 1645	MADE IN 1644	MADE IN 1643	MADE IN 1642	MADE IN 1641	MADE IN 1640	MADE IN 1639	MADE IN 1638	MADE IN 1637	MADE IN 1636	MADE IN 1635	MADE IN 1634	MADE IN 1633	MADE IN 1632	MADE IN 1631	MADE IN 1630	MADE IN 1629	MADE IN 1628	MADE IN 1627	MADE IN 1626	MADE IN 1625	MADE IN 1624	MADE IN 1623	MADE IN 1622	MADE IN 1621	MADE IN 1620	MADE IN 1619	MADE IN 1618	MADE IN 1617	MADE IN 1616	MADE IN 1615	MADE IN 1614	MADE IN 1613	MADE IN 1612	MADE IN 1611	MADE IN 1610	MADE IN 1609	MADE IN 1608	MADE IN 1607	MADE IN 1606	MADE IN 1605	MADE IN 1604	MADE IN 1603	MADE IN 1602	MADE IN 1601	MADE IN 1600	MADE IN 1599	MADE IN 1598	MADE IN 1597	MADE IN 1596	MADE IN 1595	MADE IN 1594	MADE IN 1593	MADE IN 1592	MADE IN 1591	MADE IN 1590	MADE IN 1589	MADE IN 1588	MADE IN 1587	MADE IN 1586	MADE IN 1585	MADE IN 1584	MADE IN 1583	MADE IN 1582	MADE IN 1581	MADE IN 1580	MADE IN 1579	MADE IN 1578	MADE IN 1577	MADE IN 1576	MADE IN 1575	MADE IN 1574	MADE IN 1573	MADE IN 1572	MADE IN 1571	MADE IN 1570	MADE IN 1569	MADE IN 1568	MADE IN 1567	MADE IN 1566	MADE IN 1565	MADE IN 1564	MADE IN 1563	MADE IN 1562	MADE IN 1561	MADE IN 1560	MADE IN 1559	MADE IN 1558	MADE IN 1557	MADE IN 1556	MADE IN 1555	MADE IN 1554	MADE IN 1553	MADE IN 1552	MADE IN 1551	MADE IN 1550	MADE IN 1549	MADE IN 1548	MADE IN 1547	MADE IN 1546	MADE IN 1545	MADE IN 1544	MADE IN 1543	MADE IN 1542	MADE IN 1541	MADE IN 1540	MADE IN 1539	MADE IN 1538	MADE IN 1537	MADE IN 1536	MADE IN 1535	MADE IN 1534	MADE IN 1533	MADE IN 1532	MADE IN 1531	MADE IN 1530	MADE IN 1529	MADE IN 1528	MADE IN 1527	MADE IN 1526	MADE IN 1525	MADE IN 1524	MADE IN 1523	MADE IN 1522	MADE IN 1521	MADE IN 1520	MADE IN 1519	MADE IN 1518	MADE IN 1517	MADE IN 1516	MADE IN 1515	MADE IN 1514	MADE IN 1513	MADE IN 1512	MADE IN 1511	MADE IN 1510	MADE IN 1509	MADE IN 1508	MADE IN 1507	MADE IN 1506	MADE IN 1505	MADE IN 1504	MADE IN 1503	MADE IN 1502	MADE IN 1501	MADE IN 1500	MADE IN 1499	MADE IN 1498	MADE IN 1497	MADE IN 1496	MADE IN 1495	MADE IN 1494	MADE IN 1493	MADE IN 1492	MADE IN 1491	MADE IN 1490	MADE IN 1489	MADE IN 1488	MADE IN 1487	MADE IN 1486	MADE IN 1485	MADE IN 1484	MADE IN 1483	MADE IN 1482	MADE IN 1481	MADE IN 1480	MADE IN 1479	MADE IN 1478	MADE IN 1477	MADE IN 1476	MADE IN 1475	MADE IN 1474	MADE IN 1473	MADE IN 1472	MADE IN 1471	MADE IN 1470	MADE IN 1469	MADE IN 1468	MADE IN 1467	MADE IN 1466	MADE IN 1465	MADE IN 1464	MADE IN 1463	MADE IN 1462	MADE IN 1461	MADE IN 1460	MADE IN 1459	MADE IN 1458	MADE IN 1457	MADE IN 1456	MADE IN 1455	MADE IN 1454	MADE IN 1453	MADE IN 1452	MADE IN 1451	MADE IN 1450	MADE IN 1449	MADE IN 1448	MADE IN 1447	MADE IN 1446	MADE IN 1445	MADE IN 1444	MADE IN 1443	MADE IN 1442	MADE IN 1441	MADE IN 1440	MADE IN 1439	MADE IN 1438	MADE IN 1437	MADE IN 1436	MADE IN 1435	MADE IN 1434	MADE IN 1433	MADE IN 1432	MADE IN 1431	MADE IN 1430	MADE IN 1429	MADE IN 1428	MADE IN 1427	MADE IN 1426	MADE IN 1425	MADE IN 1424	MADE IN 1423	MADE IN 1422	MADE IN 1421	MADE IN 1420	MADE IN 1419	MADE IN 1418	MADE IN 1417	MADE IN 1416	MADE IN 1415	MADE IN 1414	MADE IN 1413	MADE IN 1412	MADE IN 1411	MADE IN 1410	MADE IN 1409	MADE IN 1408	MADE IN 1407	MADE IN 1406	MADE IN 1405	MADE IN 1404	MADE IN 1403	MADE IN 1402	MADE IN 1401	MADE IN 1400	MADE IN 1399	MADE IN 1398	MADE IN 1397	MADE IN 1396	MADE IN 1395	MADE IN 1394	MADE IN 1393	MADE IN 1392	MADE IN 1391	MADE IN 1390	MADE IN 1389	MADE IN 1388	MADE IN 1387	MADE IN 1386	MADE IN 1385	MADE IN 1384	MADE IN 1383	MADE IN 1382	MADE IN 1381	MADE IN 1380	MADE IN 1379	MADE IN 1378	MADE IN 1377	MADE IN 1376	MADE IN 1375	MADE IN 1374	MADE IN 1373	MADE IN 1372	MADE IN 1371	MADE IN 1370	MADE IN 1369	MADE IN 1368	MADE IN 1367	MADE IN 1366	MADE IN 1365	MADE IN 1364	MADE IN 1363	MADE IN 1362	MADE IN 1361	MADE IN 1360	MADE IN 1359	MADE IN 1358	MADE IN 1357	MADE IN 1356	MADE IN 1355	MADE IN 1354	MADE IN 1353	MADE IN 1352	MADE IN 1351	MADE IN 1350	MADE IN 1349	MADE IN 1348	MADE IN 1347	MADE IN 1346	MADE IN 1345	MADE IN 1344	MADE IN 1343	MADE IN 1342	MADE IN 1341	MADE IN 1340	MADE IN 1339	MADE IN 1338	MADE IN 1337	MADE IN 1336	MADE IN 1335	MADE IN 1334	MADE IN 1333	MADE IN 1332	MADE IN 1331	MADE IN 1330	MADE IN 1329	MADE IN 1328	MADE IN 1327	MADE IN 1326	MADE IN 1325	MADE IN 1324	MADE IN 1323	MADE IN 1322	MADE IN 1321	MADE IN 1320	MADE IN 1319	MADE IN 1318	MADE IN 1317	MADE IN 1316	MADE IN 1315	MADE IN 1314	MADE IN 1313	MADE IN 1312	MADE IN 1311	MADE IN 1310	MADE IN 1309	MADE IN 1308	MADE IN 1307	MADE IN 1306	MADE IN 1305	MADE IN 1304	MADE IN 1303	MADE IN 1302	MADE IN 1301	MADE IN 1300	MADE IN 1299	MADE IN 1298	MADE IN 1297	MADE IN 1296	MADE IN 1295	MADE IN 1294	MADE IN 1293	MADE IN 1292	MADE IN 1291	MADE IN 1290	MADE IN 1289	MADE IN 1288	MADE IN 1287	MADE IN 1286	MADE IN 1285	MADE IN 1284	MADE IN 1283	MADE IN 1282	MADE IN 1281	MADE IN 1280	MADE IN 1279	MADE IN 1278	MADE IN 1277	MADE IN 1276	MADE IN 1275	MADE IN 1274	MADE IN 1273	MADE IN 1272	MADE IN 1271	MADE IN 1270	MADE IN 1269	MADE IN 1268	MADE IN 1267	MADE IN 1266	MADE IN 1265	MADE IN 1264	MADE IN 1263	MADE IN 1262	MADE IN 1261	MADE IN 1260	MADE IN 1259	MADE IN 1258	MADE IN 1257	MADE IN 1256	MADE IN 1255	MADE IN 1254	MADE IN 1253	MADE IN 1252	MADE IN 1251	MADE IN 1250	MADE IN 1249	MADE IN 1248	MADE IN 1247	MADE IN 1246	MADE IN 1245	MADE IN 1244	MADE IN 1243	MADE IN 1242	MADE IN 1241	MADE IN 1240	MADE IN 1239	MADE IN 1238	MADE IN 1237	MADE IN 1236	MADE IN 1235	MADE IN 1234	MADE IN 1233	MADE IN 1232	MADE IN 1231	MADE IN 1230	MADE IN 1229	MADE IN 1228	MADE IN 1227	MADE IN 1226	MADE IN 1225	MADE IN 1224	MADE IN 1223	MADE IN 1222	MADE IN 1221	MADE IN 1220	MADE IN 1219	MADE IN 1218	MADE IN 1217	MADE IN 1216	MADE IN 1215	MADE IN 1214	MADE IN 1213	MADE IN 1212	MADE IN 1211	MADE IN 1210	MADE IN 1209	MADE IN 1208	MADE IN 1207	MADE IN 1206	MADE IN 1205	MADE IN 1204	MADE IN 1203	MADE IN 1202	MADE IN 1201	MADE IN 1200	MADE IN 1199	MADE IN 1198	MADE IN 1197	MADE IN 1196	MADE IN 1195	MADE IN 1194	MADE IN 1193	MADE IN 1192	MADE IN 1191	MADE IN 1190	MADE IN 1189	MADE IN 1188	MADE IN 1187	MADE IN 1186	MADE IN 1185	MADE IN 1184	MADE IN 1183	MADE IN 1182	MADE IN 1181	MADE IN 1180	MADE IN 1179	MADE IN 1178	MADE IN 1177	MADE IN 1176	MADE IN 1175	MADE IN 1174	MADE IN 1173	MADE IN 1172	MADE IN 1171	MADE IN 1170	MADE IN 1169	MADE IN 1168	MADE IN 1167	MADE IN 1166	MADE IN 1165	MADE IN 1164	MADE IN 1163	MADE IN 1162	MADE IN 1161	MADE IN 1160	MADE IN 1159	MADE IN 1158	MADE IN 1157	MADE IN 1156	MADE IN 1155	MADE IN 1154	MADE IN 1153	MADE IN 1152	MADE IN 1151	MADE IN 1150

FIG. 1.—SUMMARIZED STATEMENT OF PRACTICE IN RAIL MILLS OF THE UNITED STATES AND CANADA.

price of rails is a commercial question outside of the province of this paper. The increased cost of individual ingot testing is so small that it should not be a matter of much commercial importance.

There is another feature of the situation which demands and is receiving serious consideration from railway officers, consulting engineers, the steel works officials, and others. That is, the desirability, if not the absolute necessity, of increasing the weight of rail sections. A number of such sections have been designed, and some have been rolled, and the rails are in use; but there is a metallurgical feature involved which should not be overlooked.

The experience of many railways has been that their earlier rails, which were of lighter sections, gave better service than the later heavier ones, and the track men will tell you that when they cut one of the old rails they found a close, fine-grained structure, while the larger rails show a more or less coarse one. The old lighter rails permitted the fining effects of the rolling to penetrate, and, the mass of metal in their heads being comparatively small, the effect of the interior contained heat passed off sooner. The foregoing conditions result in the webs and flanges of all rails having a finer structure than their heads; therefore, as we increase the size of the rail sections we will certainly decrease their proportionate strength, and under present manufacturing conditions the heavier rails will have less resistance to the abrasive wear of the traffic. Nevertheless, there seems to be a necessity for heavier rails, and so much the better, if we can also make them proportionately stronger.

Excepting in the ability to roll rails by the use of fewer passes in the rolls, and to handle the operations mechanically and automatically, there have not been any radical changes in rail rolling. The plan of rolling reductions has remained much the same. Some experiments have been made, and various schemes have been proposed, but none of them are in active use. In my judgment, the present situation demands serious consideration, even though it should require very radical changes in the rolling machinery of the existing rail mills. If we must have rails with more metal in their heads, as well as thicker webs and flanges, it is most important that the work of reduction and formation from the, say, 8- by 8-in. section of the blooms shall be applied in a way to penetrate and fine the metal in the rail heads. I shall not here attempt to particularize the way, but no doubt a modification of the universal mill, *vide* the Gray mill for structural sections, will suggest itself as one possible way, and I know of several schemes which contemplate putting work on the top of the heads in addition to only the sides, as is the case with the present mills. If that must be accomplished to solve the problem, it can and will be done.

Once more I emphasize the truth that the physical treatment of the metal is of at least equal importance with its chemical composition.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the New York meeting, February, 1914, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Apr. 1, 1914. Any discussion offered thereafter should preferably be in the form of a new paper.

Notes on Some Heating and Cooling Curves of Professor Carpenter's Electrolytic Iron

BY ALBERT SAUVEUR, CAMBRIDGE, MASS.

(New York Meeting, February, 1914)

In an important paper on The Critical Ranges of Pure Iron¹ presented at the May, 1913, meeting of the Iron and Steel Institute, Professor Carpenter reports and illustrates the results obtained by him in determining the critical points of some very pure electrolytic iron sheet about 0.01 in. thick. The iron strip was rolled into the form of a cylinder $1\frac{1}{2}$ in. long and $\frac{1}{4}$ in. wide, weighing 42 g., the thermo-couple being inserted in a small hole in the center. The points Ac3 and Ar3 were readily detected, as well as the point Ar2, but the point Ac2 was absent from every heating curve. The author concluded from this occurrence that the conception of A2 as an independent allotropic change must be abandoned.

At the October, 1913, meeting of the American Institute of Mining Engineers, Dr. G. K. Burgess and J. J. Crowe read a paper on The Critical Ranges A2 and A3 of Pure Iron² in which they described some extremely important experiments conducted by them at the Bureau of Standards, Washington, D. C. They tested Professor Carpenter's electrolytic iron and detected a sharp and well-defined absorption of heat corresponding to the point Ac2. Professor Carpenter's failure to detect this point is explained by them on the ground that unless the iron be in a single piece entirely surrounding and in contact with the thermo-couple junction, the thermo-couple will integrate the irregular progress of the heat through the sample and the curves will lose their sharpness. In discussing Messrs. Burgess and Crowe's paper, Professor Carpenter accepted this explanation as probably accounting for the absence of Ac2 in his heating curves.

Professor Carpenter had the kindness to supply me with some of his electrolytic iron. Heating and cooling curves of this metal were taken in the metallographic laboratory of Harvard University by F. C. Langenberg by means of an electrically heated tube furnace and a Le Chatelier-Saladin self-recording thermo-electric pyrometer, as constructed by Pelin, of Paris. The electrolytic sheet was tightly hammered around the

¹ *Journal of the Iron and Steel Institute*, vol. lxxxviii (1913, I), pp. 315 to 326.

² *Bulletin* No. 82, October, 1913, pp. 2537 to 2591.

thermo-couple. These curves are shown in Figs. 1 and 2. The sharp occurrence of the point Ac2 at 765° C. should be noted.

In view of the recent and extraordinary attempt of Professor Benedicks³ to account for the presence of the Ac2 point in Dr. Burgess's samples of electrolytic iron on the ground that the latter used an alternating current for heating his furnace, it should be noted that a *direct* current was used in obtaining the curves reproduced here.

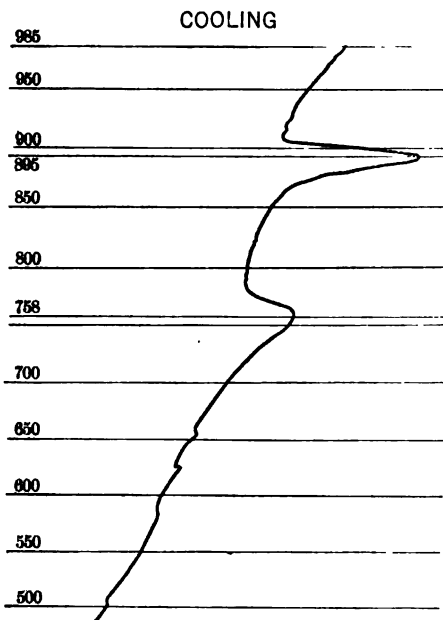


FIG. 1.—COOLING CURVE OF PROFESSOR CARPENTER'S ELECTROLYTIC IRON.

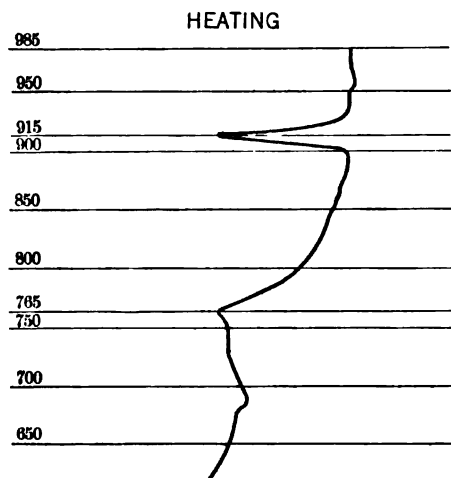


FIG. 2.—HEATING CURVE OF PROFESSOR CARPENTER'S ELECTROLYTIC IRON.

Scientific speculation is not only permissible, but highly commendable and fruitful, provided it rests on a substantial foundation of experimental facts. Scientific speculations, on the contrary, however brilliant as intellectual gymnastics, if they lack such support are merely destructive, and when indulged in by investigators of repute, their ill-founded views are likely to be accepted by others but partly informed or biased, and the progress of science be retarded.

The existence of A2 in pure iron as an independent point is no longer a debatable question. Whether this point is or is not an allotropic point appears to depend upon our conception of allotropy. If it be insisted that an allotropic point necessarily implies a crystallographic change, or, in other words, that polymorphy and allotropy are synonymous, then it may be claimed, with reason, that A2 is not an allotropic point, since crystallo-

³ *Bulletin* No. 84, Dec., 1913, p. 2877.

graphic differences between beta and alpha iron have never been discovered. On the contrary, if, more rationally in my opinion, we believe that an abrupt heat evolution on cooling and a corresponding heat absorption on heating, when occurring in a pure element without change of state, must be taken as an evidence of allotropy, then A2 must be an allotropic point. Are not such thermal disturbances due to spontaneous changes of internal energy necessarily caused by molecular changes; i.e., in the absence of change of state, by allotropic changes? We are strengthened in our belief in the allotropic character of the A2 point by the discontinuity in many of the physical properties of iron occurring at that point. It has been contended by those who doubt the allotropy of A2 that the absence of any expansion at the Ar2 point and of contraction at Ac2 argues strongly against allotropic change. Messrs. Burgess and Crowe, in the paper already mentioned, discuss this point as follows:

"Both from the work of Charpy and Grenet and of Broniewski, observations on the expansion of iron give no indication of the existence of A2. The former place the contraction observed as lying in the interval from 860° to 890° for iron with 0.03 carbon, while the latter finds it above 950° for electrolytic iron.

"This disagreement here is great enough to again raise the question, as was done by Le Chatelier in 1899, of the speed and other conditions of heating, and also whether the sensibility of the methods used was great enough to detect A2. Even its non-existence, in so far as expansion is concerned, would prove only that iron immediately above and below A2 has the same coefficient of expansion, or simply that the A2 transformation is unaccompanied by appreciable change in volume, a not unreasonable possibility. The more recent experiments of Rosenhain and Humfrey would appear to indicate a slight volume change accompanying A2." It should also be recalled that Osmond took exception to Messrs. Charpy and Grenet's conclusions drawn from their own experiments as to the absence of dilatation at Ar2. Osmond claimed that the curves obtained by Charpy and Grenet do indicate a dilatation at Ar2, the authors failing to notice it because the transformations not being sudden, the expansion likewise is gradual, whereas they were looking for sudden dilatations only.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the New York meeting, February, 1914, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Apr. 1, 1914. Any discussion offered thereafter should preferably be in the form of a new paper.

Manganese-Steel Rails

BY SIR ROBERT HADFIELD,* F.R.S., LONDON, ENGLAND

(New York Meeting, February, 1914)

SINCE the writer has been intimately connected with the development of manganese steel for many years, some remarks upon the early work with regard to the rolling and forging of this material might be of interest, and particularly as to the question of rails of special quality and of superior wearing qualities.

In a paper on Iron Alloys, with Special Reference to Manganese Steel, read before this Institute at the International Engineering Congress in Chicago in 1893,¹ the writer mentioned that, about 20 years ago, his firm in Sheffield produced railroad material, such as tires and axles, of forged and rolled manganese steel, thus showing that this product could be manipulated and worked up into the various required forms. The tires



Manganese Steel.

Ordinary Carbon Steel.

11 g. removed from manganese-steel rail by drilling in 20 min., as compared with 750 g. from an ordinary carbon-steel rail in the same time.

FIG. 1.—MANGANESE-STEEL RAIL OF $7\frac{1}{2}$ KG. PER METER ROLLED IN FRANCE IN 1904.

illustrated in the paper referred to above formed a particularly difficult class of work to produce in a special steel, but no special obstacles were met with. Although there was no difficulty at that time in making and producing manganese steel in various forms, forged, rolled or pressed; nevertheless, on account of its higher expense, sufficient encouragement

* Honorary member.

¹ *Trans.*, xxiii, 148 (1893).

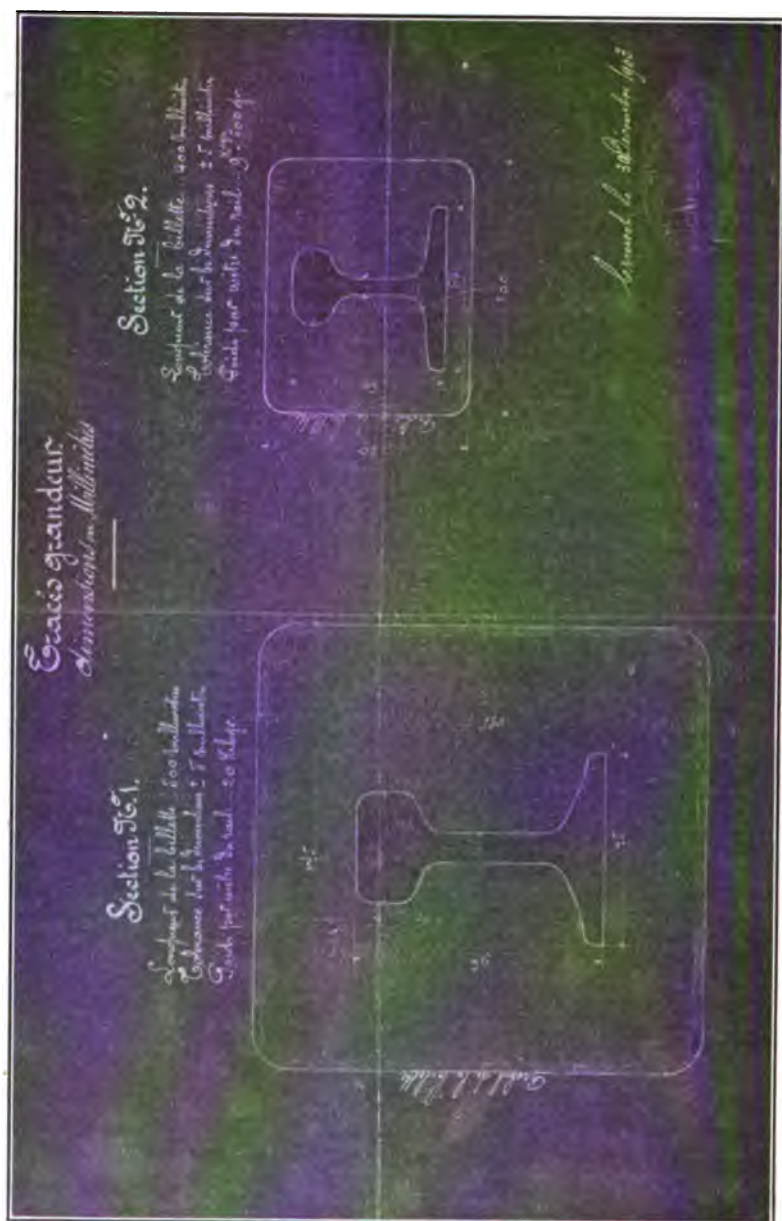


FIG. 2.—PHOTOGRAPH OF ORIGINAL TRACING PREPARED FOR THE PRODUCTION OF THE RAIL SHOWN IN FIG. 1.

was not then obtained from the users to introduce these products on a large scale. There never has been any real difficulty in obtaining forged, rolled, or pressed manganese steel, provided the consumer was willing to pay the necessarily higher cost as compared with ordinary steel.

The matter was further pursued in the present decade: In 1904, a French manufacturer produced rolled manganese-steel rails of $7\frac{1}{2}$ kg. per



FIG. 3.—SPECIMEN OF STEEL FROM WHICH RAIL SHOWN IN FIG. 1 WAS ROLLED.
BENT DOUBLE COLD. TENACITY, 60 TONS PER SQUARE INCH.
ELONGATION, 40 PER CENT.

meter, as shown in Fig. 1. The original tracing prepared by this manufacturer on Dec. 30, 1903, showing the sizes of the billets and rails to be produced, is reproduced in Fig. 2. These rails were rolled without any incident. One of them was experimented upon by the writer in the following manner: After drilling for 20 min., 11 g. of manganese steel were removed; while, in the same time, 750 g. were removed from an ordinary carbon-steel rail. The results of this test are shown in the photographic view, Fig. 1. A piece of this same manganese steel bent

double cold, as shown in Fig 3. The material showed a tenacity of 60 tons per square inch, with an elongation of 40 per cent.

This test was so satisfactory that manganese-steel rails of heavy section, 100 lb. per yard, varying from 6 to 12 m. in length, were then produced in the same rolling mill. A section of one of these rails is shown in Fig. 4.

A large number of these rails were rolled in 1907, and were supplied to the Metropolitan Electric railway of Paris (in the commencing of operations on which, it will be remembered, there was some delay), and put to work, among other places, at the Bastille station in that city. These



FIG. 4.—MANGANESE-STEEL RAIL, 100-LB. SECTION, TAKEN FROM A LOT OF 50 TONS ROLLED IN 1907 FOR METROPOLITAN ELECTRIC RAILWAY, PARIS, FRANCE.

rails, after several years of service on severe curve work, have given great satisfaction. After three years' hard service, the actual wear was found to be not more than about $2\frac{1}{2}$ mm. It has been estimated that the rails will remain in service for six to seven years before being worn out, whereas ordinary steel rails wear out and have to be replaced in less than a year. The rails in position are shown in Fig. 5.

A plant for producing sound ingots under the system devised by the writer was described in a paper² presented to the Institute at the February, 1913, meeting. This system, as adapted to the manufacture of manganese-steel ingots, is illustrated in Figs. 6, 7, and 8. No less than 90 per

² *Trans.*, xlv, 473 (1913).



FIG. 5.—MANGANESE-STEEL RAILS, 100-LB. SECTION, ABOUT 40 FT. LONG, IN PLACE AT BASTILLE STATION, PARIS, FRANCE.

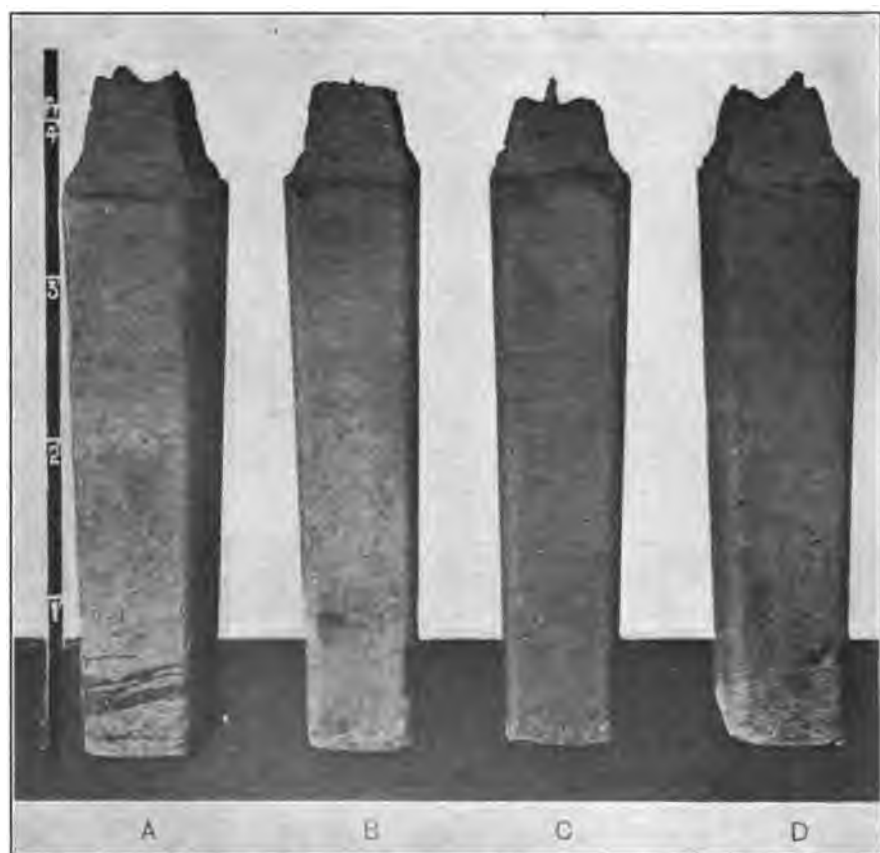


FIG. 6.—MANGANESE-STEEL INGOTS.

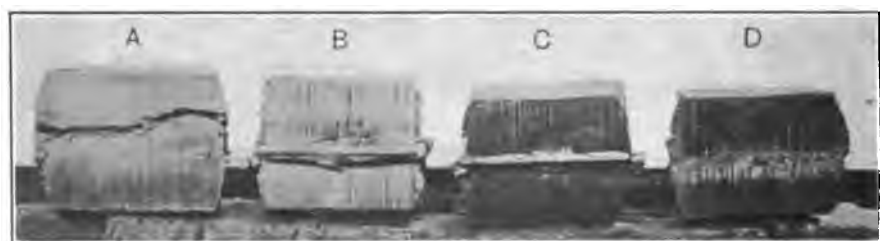


FIG. 7.—HEADS FROM ABOVE INGOTS PARTLY COGGED AND THEN CUT OFF.

cent. of sound material is obtained from an alloy steel, which will therefore be seen to offer great advantages. Each 1 per cent of expensive material saved means that much reduction in the cost of production.

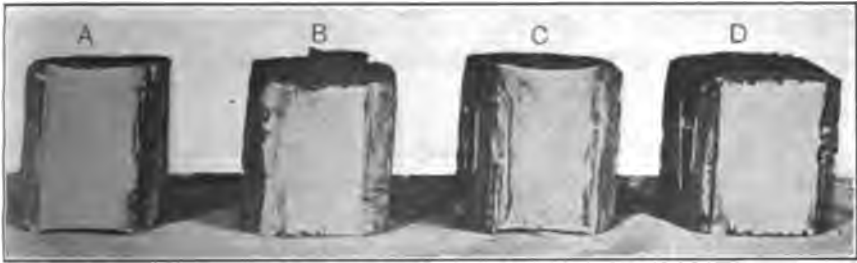


FIG. 8.—FRACTURES FROM THE UPPER END OF TOP BILLET FROM EACH OF THE INGOTS SHOW IN FIG. 6.

The consumer has now to pay for 15, 20, or even 30 per cent. of waste in special steels made in the ordinary way, whereas this waste can to a large extent be avoided. Moreover, better and more uniform quality of alloy steel can be obtained.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the New York meeting, February, 1914, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of the paper will close Apr. 1, 1914. Any discussion offered thereafter should preferably be in the form of a new paper.

Scientific Installations for the Economical Burning of Liquid Fuel of any Specific Gravity.

BY WILLIAM NEWTON BEST,* NEW YORK, N. Y.

(New York Meeting, February, 1914)

OIL burners, oil furnaces, and methods of installation, have been the subject of many articles, but information concerning oil-burning systems, based upon scientific principles, is still in great demand, especially in the manufacturing districts of our country.

Fuel oil, as it is termed (this being the residuum from oil refineries), has for many years been of great service to our manufacturers, and has justified its popularity not only by producing a superior manufactured product, but by turning out approximately 50 per cent. more product than can be made with coal fuel under like conditions. To install a system requiring only an oil-storage tank, a small pump, and an oil-supply main with numerous laterals leading to the various burners, furnaces, boilers, etc., is a comparatively simple matter; and, because fuel oil is very volatile, it is not necessary to heat it, even during the winter months in a very cold climate. Furthermore, only a small amount of power is required to atomize fuel oil, this often being done by a positive pressure blower, or by a mechanical burner. An analysis of fuel oil, together with that of various other liquid fuels, is given in Table I.

TABLE I.—*Analyses of Liquid Fuels*

	Fuel oil	California asphaltum base crude oil	Mexican (Tampico Field) crude oil
Carbon, per cent.....	84.35	81.52	83.83
Hydrogen, per cent.....	11.33	11.01	12.19
Oxygen, per cent.....	2.82	.....	0.43
Nitrogen, per cent.....	0.60	6.92	1.72
Sulphur, per cent.....	0.90	0.55	2.83
Gravity, degrees Baumé.....	26 to 28	12 to 36	12 to 23.8
Weight, pounds per gallon.....	7.3	7.6	7.82
Calorific value, B.t.u. per lb.....	18,350 to 19,348	18,462 to 18,980	18,493
Vaporizing point, degrees F.....	130	230	175

* Vice-Chairman, Committee on Petroleum and Gas.

In the middle and eastern sections of the United States, four systems for burning fuel oil have been successfully employed: namely, gravity feed; column gravity feed; the pneumatic system; and oil-pump feed.

Gravity Feed.—In the gravity-feed system, the oil is supplied to the burner from a supply tank located approximately 8 ft. higher than the burners. This is the cheapest and most simple system to install and operate, but is not approved by the National Board of Fire Underwriters.

Column Gravity Feed.—By column gravity feed, the oil is pumped from the storage tank through the supply pipes to the burners. The excess oil is then forced into a column, consisting of a pipe 2 in. in diameter and approximately 20 ft. in height, provided at the top with a vent and an overflow pipe, which carries the excess oil which overflows back to the oil-storage tank. It is obvious that by this method, the pressure maintained at any burner depends upon the difference in level between the burner and the top of the oil column. When this difference in level is 16 ft., the corresponding pressure would be approximately $7\frac{1}{2}$ lb.

The Pneumatic System.—In the pneumatic system, the compressed-air line of the factory is connected to the top of the oil-storage tank, thus putting the oil under a pressure, which may be regulated and controlled by means of an adjustable set-screw on the pressure-reducing valve on the compressed-air line. The pipe which supplies oil to the shop is coupled at or near the bottom of the oil-storage tank.

Oil-Pump Feed.—The pumping system is now most commonly used. Here a pump is employed to force the fuel from the storage tank and deliver it through a main supply pipe and laterals leading from it to the different burners. A pressure-relief valve, located at or near the pump, maintains the required oil pressure, as well as allowing the excess oil to return through an overflow pipe to the storage tank. In this system, the oil-storage tank is provided with a filling pipe, usually 3 in. in diameter; a man-hole; and a vent for the escape of gas. The regulations of the National Board of Fire Underwriters in the central and eastern parts of this country, require the tank, or tanks, to be located at least 30 ft. from any building, and to be covered with 2 ft. of earth. The type of oil pump is sometimes reciprocating, operated either by compressed air or by steam, and sometimes rotary or triplex, driven either by motor or by belt.

The Use of Oils Heavier than Fuel Oils.—The advent and popularity of automobiles and oil engines has created such a demand for by-products of fuel oil that it has now become too valuable to be used as fuel, notwithstanding its excellent quality. The manufacturing world must, therefore, install in future some system by which heavier oils can be used, and especially petroleums from the Mexican and Southern California fields, which are particularly available as fuel, because they contain so small a proportion of volatile oil, gasoline, kerosene, etc. Analyses

of Californian and Mexican crude oils are given in Table I. The completion of the Panama Canal will, no doubt, result in vast quantities of this fuel being delivered to the southern and Atlantic ports of the United States.

Efforts have been made in the eastern parts of the United States during the past year and a half, to burn the heavy petroleum from the Mexican fields, which has an average gravity of 14° Baumé. Through ignorance, when attempting to use this oil, no means were provided for heating the fuel in the storage tank; the oil pump which had been used for ordinary fuel was not changed to adapt it for a heavier fuel; the oil pipe lines were not laid so that the fuel would be constantly in circulation; and the pressure valve was not located appropriately for the heavier oil. The result was that the fuel system had to be shut down until the oil had been removed from the tanks by buckets.

I have often been amused by the efforts of persons who were accustomed to burn fuel oil, but who were not familiar with the use of heavy crude oils. For, notwithstanding that the heavy crude oil, when appropriately handled, is a better fuel than ordinary so-called fuel oil, because it has a higher calorific value per gallon, nevertheless, these efforts have often resulted in crude oil being condemned.

Oil-Burning Systems.—The system shown in Fig. 1, by the use of which any petroleum from 12° to 46° Baumé can be scientifically used as a fuel, comprises: an oil-storage tank provided with a 5-in. filling pipe, a $\frac{3}{4}$ -in. steam coil, a man-hole, a vent pipe, an overflow pipe, a suction-pipe flange, etc., as required by the National Board of Fire Underwriters; an oil pump of adequate proportions operated by steam or compressed air, or, if it be a triplex pump, driven by a belt or motor; and an oil-supply pipe so located that it follows the line of furnaces, boilers, kilns or other equipment, without the use of laterals, and with riser pipes from oil-supply pipe to burners, each of which must not exceed 3 ft. in length. The system must also include an appropriately located pressure-relief valve, and, adjacent to it, a by-pass valve to drain the oil-supply pipes when the system is not in service. An overflow pipe is connected with the relief valve and also with the by-pass valve, so that the excess oil will be led back to the storage tank. This system insures a constant, perfect circulation of the oil to each burner, and eliminates all dead ends on the supply lines.

Coating the oil-pipe threads with a paste consisting of litharge and glycerine before assembling, will prevent leakage. The unions should be ground joint. Gum or rubber should never be used, and lead gaskets should be used in flanges. I deem it always advisable to use malleable-iron beaded fittings on all oil-pipe lines.

Heating the Oil.—The object of heating the crude oil is to reduce its viscosity, and it should be heated in the storage tank to a temperature

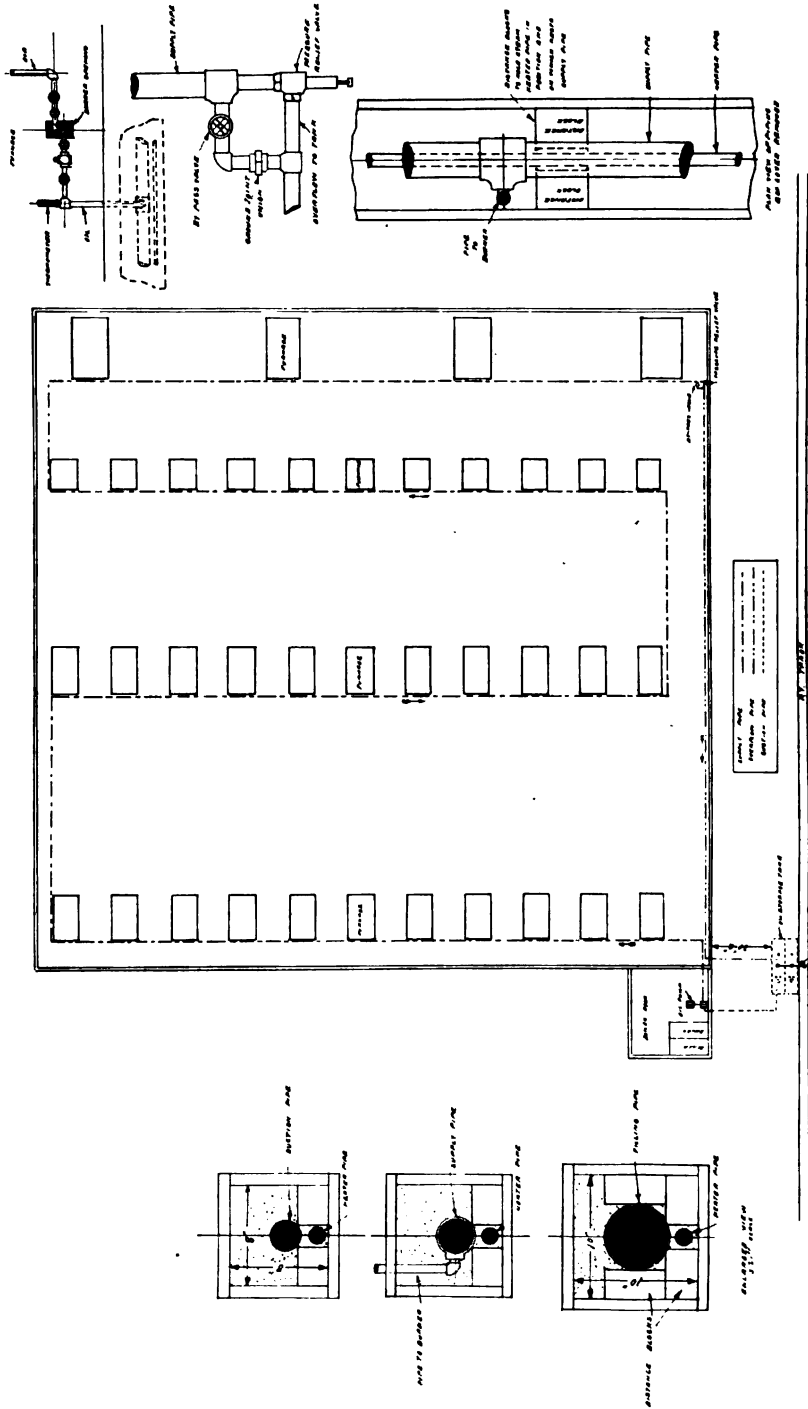


Fig. 1.—OIL-BURNING SYSTEM FOR PETROLEUM BETWEEN 12° AND 46° BAUMÉ.

that will allow it to be pumped easily. The oil is also heated in the supply and overflow pipes by running a steam pipe alongside of them, and inclosing both in an 8-in. square box which, when the pipes have been tested, is filled with dry sand. By regulating the amount of steam passing through the heater pipe, the oil is supplied to the burners at a temperature just below its vaporizing point. When the pipes are inclosed in the manner described only a small quantity of steam is needed, and, by laying the steam pipe below the oil pipe in the box, it is accessible at all times. Some persons prefer to heat the oil by passing a 3/8-in. steam pipe through the oil-supply pipe. The first cost of this is cheaper, but, if the steam pipe should leak, it is difficult to make the necessary repairs.

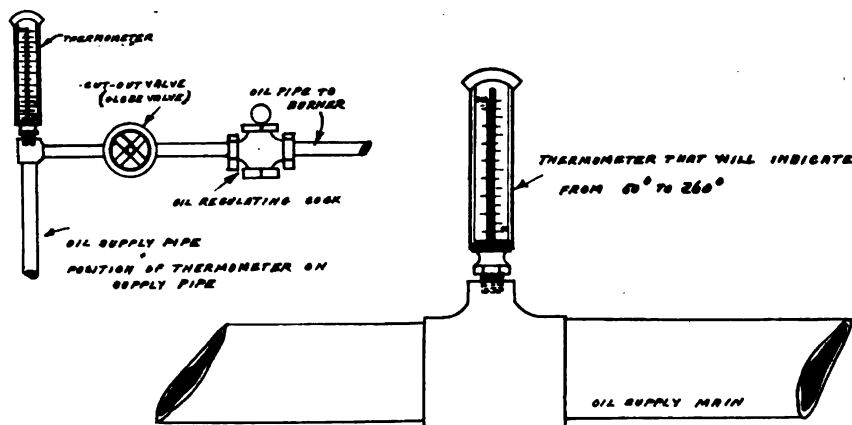


FIG. 2.—POSITION OF THERMOMETERS ON OIL-SUPPLY MAIN.

Accurate Temperature Required.—The economic advantage of accurately heating the oil to the desired temperature is shown by some tests in which a saving of 20 per cent. of Mexican crude oil required was made by heating it to 160° F. (which is 10° below its vaporizing point) instead of 120° F. The control of temperature is so important that thermometers should be used in direct contact with the fuel as it passes to the burner (see Fig. 2). Two or three such thermometers, well located, will save much oil and increase the output of the furnaces. The overheating of the oil is an example of carelessness which should be severely condemned, and which may readily be detected by the puffing of the burner, due to escaping vapor.

Liability to Fire through the Use of Oil.—There is less liability of fire from liquid fuel, employed by means of a modern fuel-supply system, than there is from the use of coal or coke, yet there are many different rules prevailing in different parts of the country for the location of oil-storage tanks. In the eastern and middle sections of our country, the

law of the National Board of Fire Underwriters require all storage tanks to be placed 30 ft. from any building and covered by 2 ft. of earth, while in San Francisco they are placed in the space formerly used for coal, immediately under the sidewalk, and are filled by oil-tank wagons or oil-tank cars from the street.¹ I have at hand evidence which proves that, of the hundreds of oil-storage tanks located in the city of San Francisco at the time of the late earthquake and disastrous fire, not one exploded or increased the conflagration or was the direct cause of financial loss. It is impossible for many manufacturers to place oil-storage tanks 30 ft. from any building, because their buildings cover their entire ground, and the Fire Underwriters' law quoted forbids them to be placed under the

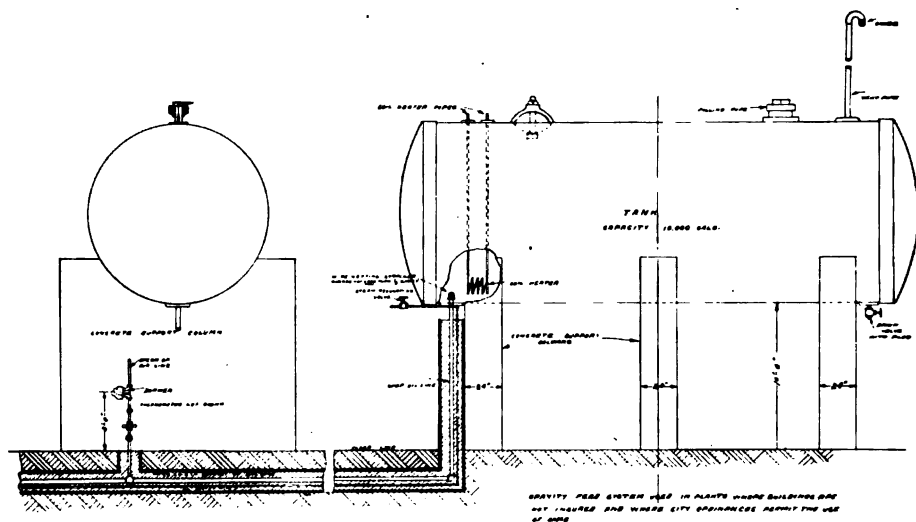


FIG. 3.—GRAVITY-FEED OIL-BURNING SYSTEM.

sidewalks. This places some manufacturers at an unfair disadvantage in competition with others, because it prohibits them from the use of crude fuel for such purposes as the heat treatment of metals, drop forging, welding, etc.

All manufacturers are to-day looking for quantity as well as quality of output, and, as oil can be safely stored under the street sidewalk in one section of the country, then, why can it not in another section? In other words, why should we not have uniform laws? If crude oil were as volatile as gasoline, there might be some grounds for fear, but it is not. As far as the danger from dripping oil is concerned, it may be obviated

¹ Resolution of Executive Committee adopted Aug. 20, 1901, by Board of Fire Underwriters of the Pacific. Circular No. 185.

by sprinkling over the floor of the pump house, and around the storage tank, a mixture of 8 lb. of sodium carbide with 1 bushel of sawdust.

Tar as a Fuel.—The present rapid increase in the use of by-product coke ovens makes available an excellent fuel in the tar which is obtained as a by-product, to the extent of about 10 gal. per ton of coal coked. Many steel works have found it to their advantage to burn this tar, which is usually conveyed to the burners by gravity, the storage tank, as shown in Fig. 3, being placed 3 or 4 ft. above the burners, being provided with a heater coil and with heater pipes running alongside the supply pipes, substantially as described above. Steel plants are seldom insured, and any plant which does not carry insurance can burn heavy oil successfully in the same manner.

“Water-gas tar” is a residuum from gas works using the water-gas system, and is an excellent fuel, which has a calorific value of 16,970

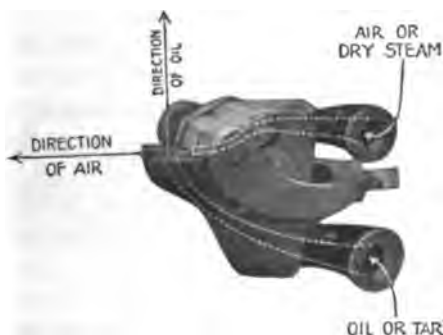


FIG. 4.—FUEL-OIL BURNER.

B.t.u. per pound, equivalent to 161,200 B.t.u. per gallon, there being 9 1/2 lb. of this tar per gallon. It is ordinarily supplied as fuel under the boilers of the plant by the gravity-feed system just described.

Burners.—Burners should be constructed so as to atomize liquid fuel of any specific gravity purchasable in the open market without changing any of the parts and without carbonization. One form of burner is shown in Fig. 4. Burners should be simple to operate, and as few as possible should be used in each equipment. The flames should fill the fire box, or charging space, of the furnaces, completely, in order that the heat may be evenly distributed. If mechanical burners are used, the oil pressure should be sufficient to insure complete atomization, and the construction of the burner should be such as to provide either a round or a flat flame, as required. If atomizing burners are used, the pressure of oil and air or steam must be constant, because any fluctuation in the pressure of either the oil or the medium used for atomizing will give a variation in the kind of flame and in the temperature. For example, we may have

alternatively a flame that is oxidizing, reducing, or smoky, whereas the combustion system should give complete control of the kind of flame whenever necessary. A smoky flame should always be avoided, because it causes loss of fuel and decrease in temperature. Technically speaking, carbon dioxide indicates perfect combustion, while carbon monoxide shows imperfect combustion.

Kinds of Service for which Liquid Fuel is Suitable.—The burning of liquid fuel is a science, and only by burning it scientifically can successful results be obtained. To condemn oil fuel is simply an exhibition of ignorance, for it has been thoroughly tested throughout the eastern and middle States, and the heavy California oil has been successfully burned in every form of service on the Pacific coast for the past 25 years. Petroleum of low specific gravity is the fuel of the twentieth century, and the demand for it will increase every year from every manufacturing nation which endeavors to keep pace with modern progress. No fuel has, however, been so wastefully used as petroleum. For example, many open-

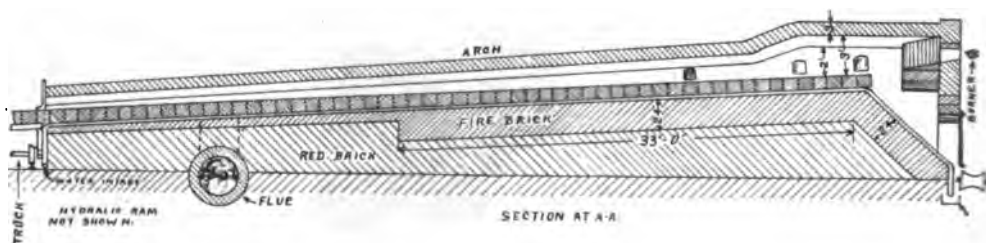


FIG. 5.—CONTINUOUS HEATING FURNACE FOR BILLETS.

hearth furnaces require 61 gal. of oil to produce a ton of steel; whereas, 32 gal. should be sufficient, and I could mention 20 other instances showing equally great variations. A continuous billet-heating furnace, 66 by 10 ft., is shown in Fig. 5.

Petroleum should be used only in those classes of work in which it is more economical than coal, coke, or gas. I regret to say that in many instances it has been employed where it could not possibly compete in price with other fuels produced in the immediate vicinity. Comparisons may be readily made by the following figures: Assuming that the petroleum has the calorific value given in Table I, and assuming that good bituminous coals have calorific values of 14,000 B.t.u. per pound, then, in good drop-forge practice, 60 gal. of oil would be equivalent to 1 long ton of coal; in boiler practice, under like conditions, 147 gal. of oil would be equivalent in evaporating power to 1 long ton of coal; in welding locomotive flues, 58 gal. of oil are equal to a ton of coal, and in locomotive service on an average division, one can ordinarily estimate that 180 gal. of oil are equivalent to a ton of coal. In locomotive service,

the use of oil eliminates the smoke nuisance and the loss caused by the burning of ties, grain fields, forests, or buildings. In large forging plants 82 gal. of oil will do the work of a ton of coal. The use of oil has, of course, the advantage in the matter of there being no ashes to handle, and, in a large plant, one man can fire and water-tend a battery of 12 oil-fired boilers with perfect ease.

During the past five years, oil has been much in demand to increase the efficiency of boilers by supplementing the coal fire during the peak of the load, and has also proven so valuable for emergency boilers in water-power plants, etc., that the actual cost is not considered in this service.

Three barrels of oil (42 gal. per barrel) are equivalent to 4,615 lb. of hickory; 4,200 lb. of white oak; 4,400 lb. of yellow pine. Six gallons of Texas crude oil are equivalent to 1,000 cu. ft. of natural gas.

The calorific value of petroleum produced in all sections of the world is about the same, while the calorific value of coal varies greatly. For example, the calorific value of Pocahontas coal is 15,391 B.t.u. per pound, while that of Illinois coal is only 10,000 B.t.u. per pound.

I give these data simply to show that it requires actual operating tests in different classes of service to obtain a definite comparison between the relative value of oil, coal, wood, and gas, as fuel. To attempt to make such a comparison by calculating with the calorific values of the various fuels is only misleading, because heat is required to liberate the gases of coal, and in welding, for example, you must first coke your fire when using bituminous coal, and therefore there is a two-fold waste of fuel; namely, the heat required to liberate the gases and the waste of heat while coking the fire, because it is impossible to weld with a green fire. In flue-welding locomotive flues, commonly termed in railway shops "safe-ending," one can attain and maintain a welding temperature by using modern oil furnaces, and 60 flues can be welded per hour; using coal instead, it is good practice when 14 to 16 flues are welded per hour with the same number of men. Thus the use of coal in this service involves a waste of both time and fuel.

In California, where petroleum is cheap and coke is costly, oil-fired air furnaces should be used, instead of coke-fired cupolas, for making gray iron castings, because oil produces a better quality of metal with a higher tensile strength and the furnace up-keep is less. Fig. 6 is a sectional view of a 12-ton air furnace. California petroleum is low in sulphur, while Mexican oil is high in sulphur, but all consequent difficulty can be obviated if a combustion chamber is used on the furnace and the proper amount of air is admitted under the flame at the correct time and place. If some inventor, having the audacity of genius, would invent an oil-fired cupola of modern construction, it would be a great blessing to those in the foundry practice who are situated where oil can compete in cost with coke in present cupola practice, and, as such a process would

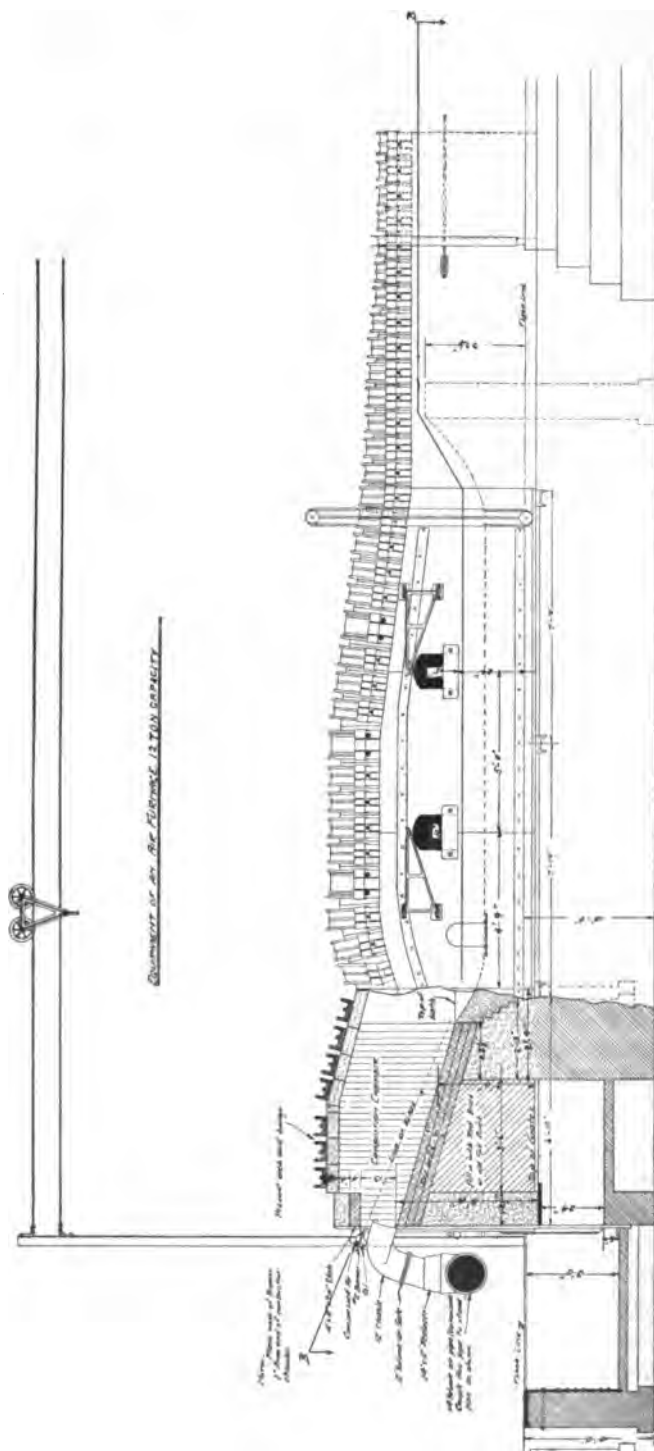


FIG. 6.—TWELVE-TON AIR FURNACE OPERATED WITH ONE BURNER.

occupy but one-fourth of the shop space of a corresponding air furnace, it would be in great demand.

The value of certain steels depends upon their heat treatment, and, because of the perfect distribution of the heat and the absolute control over the temperature, oil is an incomparable fuel for this purpose.

In the types of service mentioned below, the use of oil has been thoroughly tested, and it has been found to be an ideal fuel, but, of course, the economic effect will depend upon the relative price of oil and coal in the locality where the industry is carried on: For annealing, for asphaltum mixers. Babbitt heating, bolt making, brass melting, brazing, bread ovens, etc., brick and art-tile kilns, case hardening, cast-iron melting, rotary cement kilns, channel-iron heating, chocolate-bean roasting, continuous heating, copper-plate heating, copper refining, core drying, crematories, crucible brass melting, crucible steel melting, drop forging, enameling, flue welding, glass lehrs, glass melting, incinerators, indirect-fired furnaces, japanning ovens, ladle heating, locomotive steam raising, locomotive-tire heating, malleable-iron and gray-iron air furnaces, mold drying, ore smelting, plate heating, pipe bending, pipe-flange welding, portable torches, rivet making, rolling-mill work, rotary kilns, shaft and billet heating, sand drying, sheet-steel heating, steel melting, steel mixers, tar stills, tempering, welding scrap iron, wire annealing, wire making, as well as stationary, marine, and locomotive boilers of all types and capacities.

In conclusion, I refer to an exhaustive report compiled in 1904 by the Liquid Fuel Board of the United States Navy. The test was under the direction of the late Rear Admiral George W. Melville, but the work was done by the President of the Liquid Fuel Board, one of our honored members, Rear Admiral John R. Edwards. This report stands to-day as the highest authority in marine boiler practice. The fuels used were procured from various sections of the United States, and these tests brought liquid fuel to the attention of the world, with the result that all the leading nations are installing it on their battle ships, and some authorities believe that the liquid-fuel question is one which may determine the relative naval strength of the nations. It should, therefore, be our aim as loyal Americans to obtain as wide a knowledge of this fuel as possible, and we believe that the American Institute of Mining Engineers was not only serving the best interests of the manufacturing world, but those of our nation, when it established the Committee on Petroleum and Gas, to promote research on this important fuel, the supply of which we believe to be fully equal to the demand, as has been the case with coal, natural gas, and other fuels.

TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.
[SUBJECT TO REVISION]

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the New York meeting, February, 1914, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Apr. 1, 1914. Any discussion offered thereafter should preferably be in the form of a new paper.

Drilling Performances at the Kensico Dam, Catskill Aqueduct System, New York

BY W. L. SAUNDERS, NEW YORK, N. Y.

(New York Meeting, February, 1914)

General Description of the Work

WHEN work was begun in September, 1910, on the rock excavation for the foundation of the gigantic dam at Valhalla, N. Y., which is to convert Kensico lake into an important storage reservoir of the Catskill Aqueduct



FIG. 1.—SITE OF THE NEW KENSICO DAM.
Part of the old Kensico Dam at Extreme Left.

system, one of the first steps taken by the contractor, H. S. Kerbaugh, Inc., was the development of a quarry to supply the stone needed in the

construction work. The importance of a bountiful supply of suitable rock in an accessible location is apparent when it is considered that nearly a million cubic yards of cyclopean masonry will be contained in the completed structure, not to mention dimension and facing stones, concrete blocks, and mass concrete.

The dam structure will be over 1,800 ft. long and about 170 ft. above the present river bed. However, for a distance of some 800 ft., it will be carried down to solid ledge rock, which will make the finished structure about 300 ft. in maximum height. It will be about 200 ft. thick at the base and directly beneath the coping it will be 28 ft. thick.

This dam will raise the reservoir surface 110 ft. above old Kensico lake. The reservoir capacity will be 29,000,000,000 gal.—equal to New York's total needs for over two months.

The contract price for this work is nearly \$8,000,000 and is second only in amount to the cost, over \$12,600,000, of the Ashokan Reservoir work. Fig. 1 is a view of the dam site.

The Quarry

The quarry site is about a half mile away from the dam. The rock is a clean and practically flawless gneiss having a tendency toward granite. In some places, however, it is seamy, presenting more or less difficulty to drilling, but in the main it is hard and solid. The rock surface is fairly level, affording a good footing for the drilling apparatus.

Thirty tripod drills and four drill wagons, all of the electric-air type, were purchased for this work, but the drilling has progressed so rapidly that enough holes have been put in to supply rock for a year or two, consequently most of the drills and operators have been laid off and only a few tripod drills and the four drill wagons are in operation at the present time.

Tracks run from the quarry directly to the dam site; a main line with several branches has been cut into the various parts of the quarry. The drills are mounted on the high rock adjacent to these cuts and put in rows of holes parallel with the tracks, all bottoming at a common level. After the holes are drilled to depth, wooden plugs are inserted to keep dirt from entering them. (See Fig. 2.) A great number of holes are shot simultaneously, loosening up a large area of rock at a single blast, as shown in Fig. 3. The rock is removed and placed on flat cars by 90-ton steam shovels, which advance along the track after the blast.

Stone of suitable size is removed bodily and imbedded in the concrete at the base of the dam and in the dam structure. The remaining rock is conveyed to a large rock-crushing plant located adjacent to the quarry, where it first goes through a gigantic jaw crusher, then through smaller crushers, is screened, falls by gravity into dump cars and is transported



FIG. 2.—A BATTERY OF HOLES IN THE QUARRY READY FOR BLASTING.



FIG. 3.—AFTER A BLAST AT THE QUARRY.

to the dam. The large jaw crusher was designed to crush exceptionally large stones, thus avoiding considerable labor incident to pop-shooting.

Power

Electric power operates all of the apparatus at both dam and quarry, excepting the locomotives and steam shovels. The transmission line for the three-phase, 60-cycle, 66,000-volt alternating current extends about 4 miles, from Yonkers to a sub-station near the reservoir site, following the Aqueduct right-of-way. The sub-station contains six transformers which reduce the voltage to 2,200. Pole-type transformers of either 488 or 244 volts are employed for stepping down the current for the machines. The wires are carried along the ground to the individual drilling machines.

Locomotives and cars are used mainly for conveying the material. Traveling cranes, operating on parallel tracks, place the building material. Each traveler has two derricks equipped with geared electric hoists. There are eight travelers which operate on different sections of the structure in batteries of four. The two interior tracks for the travelers and two exterior tracks for the cars are supported on concrete piers.

The dam site has been spanned by two 10-ton aerial tram cableways, each 1,860 ft. in length, the towers for which are seen in the background of Fig. 1. These are employed in an auxiliary capacity, principally to set the concrete block piers for the tracks and to raise the tracks as the work progresses.

Performance of Electric-Air Drills

It was desired to determine the cost and speed of drilling operations at the dam and quarry and for this purpose time studies were undertaken by the Construction Service Co. during the early part of the summer of 1913.

In general, the electric-air drill (Fig. 4) consists of two units, the drill proper and the pulsator. In appearance the drill closely resembles the compressed-air drill of corresponding size, having, however, a cylinder somewhat larger in diameter and with a shorter piston. It is mounted in the usual manner upon a tripod. The pulsator alternately furnishes air to either end of the drill cylinder and the same air is used over and over again in a closed circuit. Two lengths of rubber hose connect pulsator and drill, each acting alternately as supply pipe and exhaust. The pulsator is geared to a small alternating current motor, both mounted on a rigid truck to facilitate handling. Pulsator, motor, and truck weigh about 800 lb.

The ordinary air or steam driven rock drill takes a full cylinder of

air or steam at full pressure for each stroke, and exhausts to atmosphere at practically full pressure. No advantage, therefore, is taken of the expansive properties of the actuating fluid, which results in a certain amount of power being wasted without accomplishing useful work. The closed system of the electric-air drill, however, is filled with air under a low pressure, and this air is never exhausted, so that the expensive effect is turned directly to profitable account. Leakage is provided for



FIG. 4.—ELECTRIC-AIR DRILLS PUTTING IN HOLES FOR THE CUT-OFF TRENCH AT THE UP-STREAM SIDE OF THE DAM.

Changing steels on the Drill in the foreground.

by a compensating valve on the pulsator which automatically keeps the volume of air in the system constant. The drill has no chest nor valves and the pulsator has neither operating valves nor water jacket.

The drills observed are known as Temple-Ingersoll Type 5-F, and the pulsators are driven by motors rated at about 5 h.p., operating on 14.6 amperes at 220 volts. The cylinder diameter is $5\frac{1}{2}$ in. and the length of stroke 8 in. The length of feed, or depth of hole that can be drilled

without change of bit, is 30 in., but during observation the bits were usually changed after about 25 in. had been drilled. The strokes per minute were about 400 at full speed.

The drills were operated and handled by the drill runner and one helper and moving was accomplished by hand. The method of dismantling is about the same as with the ordinary tripod drill except that in the case of the electric-air drills there is the added weight of the mounted motor and pulsator to be moved.

The diameter of the starting bits was $3\frac{1}{2}$ to 4 in. and decreased $\frac{1}{8}$ in. for each succeeding length of steel down to $1\frac{1}{2}$ in. for the deepest holes. The steels varied from 2 ft. 6 in. to 28 ft. 8 in. The steels were octagonal in section, from $1\frac{1}{2}$ to $1\frac{1}{2}$ in., with square cross bits. The shorter steels were handled by one man and the longer ones by the driller and helper, sometimes with the aid of a hook.

Two forms of chuck were observed, one a bolted chuck, and the other consisting of a sleeve sliding on a tapered key and bearing directly on the drill steel. The time required to insert the steel in the chuck and to tighten the chuck was considerably greater in the case of the former type than in that of the sleeve type, as noted in the time study made at the quarry. Both types appeared to be equally efficient.

The spacing of holes at the quarry varied from 15 by 12 ft. to 20 by 20 ft. The holes were all vertical and varied in depth from 10 to 26 ft. The number of holes shot at the quarry depended upon the quantity of rock needed in the construction work. Generally, the method employed for cleaning the holes was to pour water into them and bail out with sand pumps when changing steels.

The sharpening shed at the quarry was situated some distance from many of the drills in operation, hence there were occasional delays in receiving sharpened steels, during which time some of the drills were idle. The steels were sharpened by hand at the dam and by a Leyner drill-sharpening machine at the quarry.

The smith's work consisted of sharpening the drills and also included other repair work. He estimated that 75 per cent. of his time was devoted to the drill steels. The estimate of coal burned by the smith was 500 lb. per day.

Sticks of 60 per cent. Dupont dynamite, $1\frac{1}{2}$ in. in diameter by about 8 in. in length, weighing 12 oz., were used. Dupont exploders were employed. The blasting charge at the quarry was calculated to average about $\frac{1}{2}$ lb of dynamite per cubic yard of rock. The charge was set off by means of electricity. The blasting gang on the day of observation consisted of one loader and two tampers.

The oil consumption of the drills was about 3 quarts each per shift. The power consumption was from 30 to 40 kw-hr per drill per shift. There was one 8-hr. shift per day.

Time Study of Drilling Performance of Electric-Air Tripod Drills at the Quarry

Observations recorded in minutes and seconds

	No. of obs.	Minimum M S	Average M S	Maximum M S	Actual time M S	Consumed time per cent. of total time
Drill cutting.....	16	5-40	14-18	23-28	228-54	51.1
Raising drill.....	15	0-05	1-05	1-59	16-13	3.6
Loosening chuck a....	7	0-02	0-11	0-45	1-16	0.3
b....	3	1-06	1-27	1-46	(4-20) ^c	....
Removing bit.....	12	0-03	0-32	1-54	6-26	1.4
Bailing hole.....	11	0-45	1-23	2-00	15-10	3.4
Putting bit in hole....	12	0-10	0-22	0-55	4-20	1.0
Inserting bit in chuck.	16	0-10	0-23	0-40	6-12	1.4
Tightening chuck a....	6	0-05	0-10	0-20	1-00	0.2
b....	10	0-38	0-53	1-20	8-46	2.0
Getting started.....	17	0-00	1-01	6-23	17-13	3.8
Cycle totals.....		8-44	21-45	41-30	305-30	68.2
Shifting drill.....	4 ^d	35-32	52-00	60-00	73-18 ^e	16.4
Miscellaneous delays	11	0-30	6-17	25-40	69-05	15.4
Total.....					447-53	100.0

Linear feet drilled, 31 ft.; average depth of holes, 22 ft.; total working time, 7 hr. 27 min. 53 sec.

a Sleeve chuck.

b Bolted chuck.

c This figure is not included in "Cycle Total" for this operation was performed by one man at the same time that the other man was raising the drill.

d During one observation a nearby derrick assisted in moving the drill saving several minutes.

e Inasmuch as a shift was made after every 22 ft. of hole the time for shifting properly chargeable is $\frac{3}{2} \times 52 = 73-18$. Several observations were taken simultaneously on different drills to ascertain a fair average time required to shift before deciding upon 52 min. as the average.

From the above table it appears that the average cutting speed was 0.135 ft. per minute. The ratio of cutting time to total time was 0.511 and the ratio of idle time (including the time for shifting drills) to cycle time was 0.467.

Based on the above performance at the quarry, the following costs per linear foot drilled and per cubic yard loosened have been deduced: 1 drill cut 31 ft. in 447 min. 53 sec.; equivalent to 200 ft. by 6 drills in

one day of 8 hr. The average spacing of the holes being 17.5 by 16 ft., the corresponding cubic yards loosened was

$$\frac{200 \times 17.5 \times 16}{27} = 2,070 \text{ cu. yd.}$$

Standard Basis of Costs

At the Quarry

	Rate	Amount		Cost per linear foot	Cost per cubic yard
				Cents	Cents
6 drillers.....	\$2.50	\$15.00			
6 driller helpers.....	1.75	10.50	\$25.50	12.75	1.23
1½ blacksmith.....	3.00	4.50			
1½ blacksmith helpers.....	1.75	2.63			
2 nippers.....	1.50	3.00			
2 mules.....	1.50	3.00	\$13.13	6.57	0.64
Total labor (drilling).....		\$38.63		19.32	1.87
Coal, 500 lb.	3.50	0.87			
Oil, 3 qt. per drill.....	0.30	1.35			
Power, 35 kw-hr.....	0.01	2.10	\$4.32	2.16	0.21
Total drilling cost.....		\$42.95		21.48	2.08
Interest and depreciation, 2 per cent. per month.		7.70		3.85	0.37
			\$50.65	25.33	2.45
3 powdermen.....	2.00	6.00			
1,035 lb. dynamite.....	0.12	124.20			
25 explodera.....	0.03	0.75	\$130.95	65.47	6.32
Total.....		\$181.60		90.80	8.77

In the foregoing no account has been taken of contractor's overhead charges, superintendence, storage, repairs, preparatory costs, insurance, charity, accidents, legal or medical expenses, etc.

The low cost per cubic yard is due to the unusually wide spacing of the holes, which were loaded with a heavy charge of dynamite.

Time Study of Drilling Performance of Electric-Air Tripod Drills at the Dam

Observations recorded in minutes and seconds

	No. of obs.	Minimum M S	Average M S	Maximum M S	Actual time M S	Consumed time per cent. of total time
Drill cutting.....	12	6-23	11-35	21-24	139-00	58.9
Raising drill.....	11	0-10	0-51	2-00	9-22	4.0
Loosening chuck.....	12	0-00a	0-09	0-25	1-45	0.7
Removing bit.....	12	0-00b	0-29	1-10	5-42	2.4
Bailing hole.....	10	1-43	1-36	2-42	16-01	6.8
Putting bit in hole....	10	0-18	0-45	2-09	7-34	3.2
Inserting bit in chuck.	10	0-05	0-25	0-55	4-08	1.7
Tightening chuck.....	11	0-02	0-14	0-40	2-30	1.1
Getting started.....	10	0-02	0-13	0-45	2-08	0.9
Cycle totals.....		8-43	16-17	32-10	188-10	79.7c
Shifting drill.....	2	9-03	12-00	15-00	28-48	12.2d
Miscellaneous delays..	8	0-15	2-24	9-40	19-12	8.1
Total.....					236-10	100.0

Linear feet drilled, 26.4 ft.; average depth of holes, 11 ft.; total working time, 3 hr. 56 min. 10 sec. The cutting speed was 0.190 ft. per minute; ratio of cutting time to total time was 0.589; ratio of idle time (including shifting of drills) to cycle time was 0.255.

a Chuck loosened by one man simultaneously with raising of drill by other.

b Bit removed by one man simultaneously with raising of drill by other.

c The percentage of "Cycle Total" is higher in this case than at the quarry, due mainly to the fact that the delivery of sharpened steels to the drillers was more prompt.

d For the same reasons as given in the note under "Shifting Drill" in the quarry time study, the time for shifting properly chargeable in this case is $\frac{26.4}{11} \times 12 = 28 - 48$.

Based on the performance, at the dam pit, of one drill doing 26.4 linear feet in 236 min. 10 sec., six drills would accomplish about 320 ft. per day.

During observation, the spacing of holes at the dam was very irregular. The diagram (Fig. 5) shows the approximate spacing of the holes at the time this observation was made. The drills were at work on the cut-off trench on the up-stream side of the dam. The wide cut, at a rough estimate, appeared to be nearly 200 ft. in width, but the cut-off trench was only about 15 or 16 ft. in width and averaged about 11 ft. deeper than the main cut. The spacing of holes was very close and the blasting charges were correspondingly light. The outer rows of holes had a spacing of only 6 in. which resulted in practically smooth walls.

The total drilling cost at the quarry for six drills per day was \$50.65,

including interest and depreciation. On the same basis of costs, the performance at the pit would be at the rate of $\frac{\$50.65}{320} = 15.8$ c. per linear foot, as against 25.33 c. at the quarry. Of course, for comparative purposes, the blasting costs should be omitted, inasmuch as the amount of powder per linear foot would be much lower at the dam, due to the closer spacing and lighter loading of the holes.

For similar reasons, and because of the irregular spacing at the pit, there would be little value in a comparison of costs per cubic yard

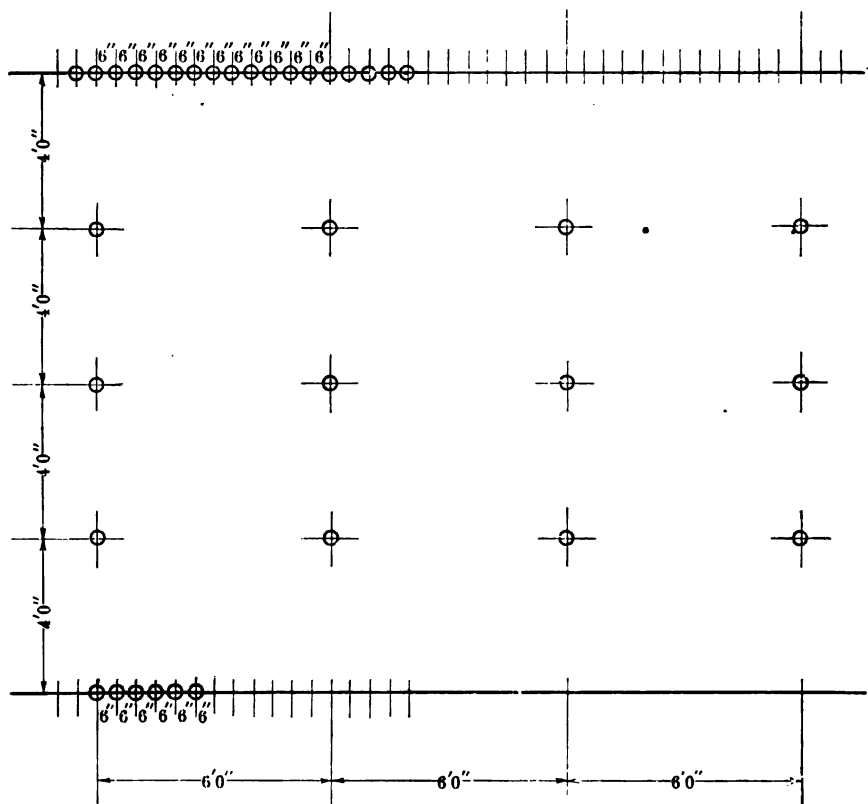


FIG. 5.—APPROXIMATE SPACING OF HOLES IN TRENCH FOR DAM FOOTING.

excavated. The cost per linear foot drilled is less at the pit than at the quarry for the reasons that the cutting speed was greater and the ratio of cutting time to total time was greater.

Electric-Air Drill Wagons

The electric-air drill wagons are putting in holes averaging about 40 ft. in depth. The holes are started at 5 in., and bottom at $3\frac{1}{2}$ in. A cross bit is used.

The drill wagon (Fig. 6) is supported on heavy planks placed on the ground, so that it is very simple matter to advance the wagon when a new set of holes is to be put in. Several holes may be drilled at one setting of the wagon as the drill mechanism is mounted on a circular rotatable platform, allowing holes to be put in on either side and beyond



FIG. 6.—ONE OF THE ELECTRIC-AIR DRILL WAGONS AT THE QUARRY.

the end of the wagon. The drill wagon has a vertical power feed of 6 ft, the drill traveling up and down in vertical guides, while a lighter and higher frame is used as a hoist for the steels. It takes them out of the hole at a single lift, excepting the very longest steels. The drill cylinder is 7 in. in diameter, 7 in. stroke, and strikes 350 blows per minute.

The pulsator and 12-h.p. electric motor operating it are both mounted on the drill wagon. In other respects the arrangement and operation resemble the Temple-Ingersoll tripod drill outfits.

By means of clutches, the motor drives the feed screw for the drill hoist and raises and lowers the steels; it also operates a winch which can be used to propel the wagon when its position must be changed.

One drill runner and a helper operate and handle the drill wagon. The shifts are of 8 hr. duration and at the time of this observation the drills were averaging about 40 or 50 ft. of hole per shift. The weather was most oppressively hot during this particular observation, which probably accounted for the relatively slow progress, as it is understood that the progress of drilling in this rock has usually averaged 45 to 65 ft. per shift and, under test conditions, as much as 104 ft. of hole has been drilled per shift. A constant stream of water is fed into the hole through a pipe beside the steel. A long bamboo pole is used for lowering the blasting charge into the hole. Electricity is employed for setting off the charges, and, as parties are working simultaneously in various parts of the quarry, the blasting can be carried on in one place while the drilling and mucking are in progress in other sections of the quarry.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the New York meeting, February, 1914, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Apr. 1, 1914. Any discussion offered thereafter should preferably be in the form of a new paper.

Notes on Blast-Furnace Operation with a Turbo Blower

BY S. G. VALENTINE, OXFORD, N. J.

(New York Meeting, February, 1914)

BLAST-FURNACE blowing engines are broadly of two main types: either steam- or gas-driven reciprocating engines, or turbine-driven rotary engines. Some results of experience with a furnace blown by an engine of the latter type may be of sufficient general interest to relate. The first engine of this type was installed at Oxford Furnace, New Jersey, before the writer's connection with this plant, in March, 1910. This furnace uses chiefly New Jersey magnetites and had been in blast seven months on its old engines when the turbo blower was started. It was 80 ft. high by 17 ft. 6 in. bosh and 11 ft. hearth diameter. It is of interest to see from the records what happened when the turbo engine was put to work. But of course, as the old blowing equipment was rather antiquated, consisting of two I. P. Morris engines with air cylinders 72 by 72 in., in good running order, however, it is evident that the comparison between their work and that of the turbo blower cannot be interpreted as being between machines that were respectively of equal excellence as representatives of their types. Still the results were gratifying and interesting. The records show that, with the old engines blowing 13,630 cu. ft. of air per minute, measured by piston displacement, the furnace was working up about 480 tons of stock per 24 hr. and producing an average of 132 tons per day and a maximum of 166 tons.

The rotary blowing engine installed was a General Electric Co. machine, the driving end being a Curtis steam turbine and the air end a six-stage rotary compressor, all running at about 1,500 to 1,600 rev. per minute, and having a capacity of 25,000 cu. ft. of air per minute up to 25 lb. pressure, and equipped with an automatic constant-volume variable-speed governor. After running this blower, for a period equal to that covered above by the old engines, at an average rate of 15,000 cu. ft. of air per minute, the furnace worked up an average of about 592 tons of material and produced an average of 170 tons per day. Thus, on an apparent increase of 10 per cent. in the air volume there was an increase of about 23.5 per cent. in the materials worked up and of about 28.8 per cent. in the product. For the first calendar month's operation of the turbo blower, on an average of 15,040 cu. ft. of air per minute, there is

shown an average increase of 25 per cent. in the materials worked and of 33.3 per cent. in the product.

The furnace was blown out, relined, and put in blast again in June, 1912, and has been operating ever since. The only change in the furnace lines was an increase of 6 in. in hearth diameter, making it 11 ft. 6 in. Taking the operations of the last six months of 1913, to get the average of work done, the following data are of interest: The ores used are chiefly magnetites, averaging about 85 per cent. of these and 15 per cent. of other ores. Of the 85 per cent. magnetite, about 75 per cent. consisted of roasted magnetite carrying about 0.50 per cent. sulphur. The furnace runs chiefly on basic iron, and for this six months period had averaged 223 tons per calendar day, regardless of any time lost, with an average coke consumption of 2,147 lb. per ton of pig iron on an average consumption of 14,300 cu. ft. of air per minute, equivalent to an average of 41.7 cu. ft. per pound of coke used, the maximum being 43.5 and the minimum being 39.5.

Three main items of interest are developed in practice with our turbo blower. They are the low figures shown for quantity of air used per pound of coke burnt; the delivery of this air in a continuous stream instead of in pulsations; and the automatic regularity of the quantity of air delivered. Each of these items has its effect on the furnace operation, as further discussion will develop.

The item of the quantity of blast per pound of coke was the first result of the operation of the turbo blower to attract attention, because of what seems the very low figure shown. It required some time after blowing in this furnace for a Superintendent accustomed to the usual reciprocating engine quantities to adjust himself to the apparently low blast requirements in this case. The first impression was naturally that the thing was impossible, and that the rating of blast delivered was not correct. The makers of the engine, however, assured us that their calibration of the deliveries was guaranteed correct within 5 per cent. and they considered it actually correct within 3 per cent. It may be added that the blast lines and all connections from the engine to the tuyères are tight and entirely free from any noticeable leaks. Several inquiries as to the experience of other users of turbo blowers have elicited the information in one case that they were burning a pound of coke with 51 cu. ft. of air; in another case 53 cu. ft. were used, but with the added information that the blast lines were not tightly calked and there was a very noticeable leakage through them and through the air valves of the old blowing engines to which the cold-air main was connected.

In an endeavor to check this item we can calculate from certain data about what amount of blast is actually being blown into the furnace. The 2,147 lb. of coke per ton of pig iron, at 85 per cent. fixed carbon, contains 1,825 lb. carbon, and the 1,345 lb. limestone used per ton of

pig iron, at 11 per cent. carbon, contains 148 lb. carbon. The analysis of the furnace gases shows as follows: CO_2 , 9.43; CO, 31.49; $\text{CH}_4 + \text{H}$, 0.90; N, 58.18; total, 100 per cent.

The CH_4 and the hydrogen were not separately determined, but as the quantity is small it does not materially affect the results.

	Pounds
Carbon from coke.....	1,825
Carbon from limestone.....	148
	1,973
Carbon to pig iron.....	90
Total carbon going to furnace gases.....	1,883

As there is 0.54 oz. carbon per cubic foot in either CO, CO_2 , or CH_4 , we find:

$$\text{CO}_2, 0.0943 + \text{CO } 0.3149 + \text{CH}_4, 0.0090 = 0.4182 \times 0.54 = 0.225828 \text{ oz. carbon in gas per cu. ft.}$$

$$\text{Carbon per cu. ft. gas, } 0.225828 \div 16 = 0.014114 \text{ lb.}$$

$$\text{Gas per ton pig, } 1883 \div 0.014114 = 133,413 \text{ cu. ft.}$$

$$\text{Nitrogen in gas, 58.17 per cent., would be per ton pig} = 77,606 \text{ cu. ft.}$$

$$\text{Air per ton pig, air being 79.3 per cent. N.} = 97,860 \text{ cu. ft.}$$

$$\text{Air per lb. coke, } 97,860 \div 2,147 = 45.5 \text{ cu. ft.}$$

This compares with the engine record of 41.7 cu. ft. within about 8 per cent. and would indicate that the engine calibration is at least measurably correct. An element of slight inaccuracy may lie in the gas analysis used above, as the figures do not cover this period of six months and may not be an exact average of the whole period. But the analysis gives about our normal figures and the calculation seems confirmatory of the engine rating within a reasonable degree.

Assuming that the rating is approximately correct, we are impelled to a comparison with others in this respect. From general information, but without having received the actual data, we understand other users of turbo blowers are showing around 50 cu. ft. of air per pound of coke. On reciprocating engines the figures of one good modern plant, working on Lake Superior ores, were given me as 55 cu. ft. Still another on the same make of blowing engines, working largely magnetite ores on foundry iron, shows 67 cu. ft. Another furnace with another make of reciprocating engines on magnetite mixture shows 57.6 cu. ft. Another furnace working on about two-thirds magnetites with still a third standard make of reciprocating engines used 62 cu. ft.

There are several factors that enter into any explanation of the variations shown as to the amount of air used in the above cases. In the first place, there is the item of the accuracy of the measurements. It seems that the quantities generally reported are lower on turbo blowers

than on reciprocating engines. It would be of interest to have the facts for other plants on both types of engine coupled with calculations of the air requirements based on the gas analysis, for comparison. Our own case seems to indicate reasonable accuracy as to the rating of delivery of air. In view of the fact that in most cases the ratings on reciprocating engines are considerably higher, how shall they be interpreted? We are inclined to charge part of the difference to a failure of reciprocating engines in many cases to deliver the quantities measured by piston displacement, and believe that in many cases furnaces are not actually getting the air they are supposed to get. It is a question whether cylinder capacities, clearances, character of air valve, and points of opening and cut off cover all the items in measuring the air deliveries. There is always the question as to the actual air admission on high-speed engines, and also of the delivery of the air against the varying tension in the blast main, on either high or low speed. Possibly the steady flow of air from a rotary blower as compared with the series of pulsations from a reciprocating engine may contain a factor that would furnish a partial explanation of the differences. I am willing to refer this line of discussion to those whose engineering ability better qualifies them to handle it.

A second feature to be remembered in interpreting these air quantities is the nature and physical condition of the ore to be reduced. Different ores will require different conditions in the consumption of coke in the furnace for their reduction and smelting. In certain cases the direct reduction by carbon in the upper part of the furnace will be greater than in other cases, and consequently the demand for burning carbon at the tuyères to CO will be less. On other ores again this condition will be reversed. J. E. Johnson, Jr., in a recent discussion¹ has called attention to this point with some very interesting data.

After eliminating the element of inaccuracy of measurements of the air used, the remaining explanation of any discrepancy between the actual air consumption and the amount theoretically needed to burn the carbon of the charge to CO at the tuyères must measure the loss of carbon in the upper part of the furnace, due to two causes—the waste of carbon by the action of CO₂, and the use of carbon for direct reduction of the ore. One would expect that as the former cause was the more active the requirement of coke per ton of pig would be relatively higher; and as the latter cause (direct reduction) was more active the requirement of coke per ton of pig would be relatively lower.

Taking our own case and assuming that our rating of 41.7 cu. ft. of air per pound of coke is approximately correct, let us compare the figure with what should be used if all our carbon were to be burned to CO at

¹ *Bulletin* No. 84, Dec., 1913, p. 2864.

the tuyères. This amount is readily calculated. The carbon to be burnt per ton pig is 85 per cent. of 2,147 lb. coke, or 1,825 lb., less 90 lb. carbon for the pig iron, or 1,735 lb. As it requires 16/12 or 4/3 oxygen per pound of carbon burned to CO, and 100/23 as much air to furnish this oxygen, then air required, $1,735 \times 4/3 \times 100/23 = 10,058$ lb. Air at 60° weighs 0.0763 lb. per cubic foot, so that air required per ton pig is 131,821 cu. ft., and air per pound coke is 61.3 cu. ft.

Since the theoretical amount of air needed to burn 2,147 lb. of coke is 131,821 cu. ft. and the supposed actual quantity used is $2,147 \times 41.7$ or 89,529 cu. ft., this would represent a difference of 42,292 cu. ft., which divided by the theoretical requirement, 61.3, is equal to 690 lb. of coke, 32.1 per cent., or about one-third of the coke used per ton of pig, which in our case never reaches the hearth. Whatever explanation we find for this apparently large disappearance of carbon in the upper part of the furnace must accord with the by no means extravagant coke consumption given per ton of pig for a furnace working a refractory ore mixture. While doubtless there is a certain loss of carbon by action of CO₂ on the coke, it seems likely that there is an unusually large reduction of the ore by solid carbon above the tuyères. Otherwise we would expect to see higher coke requirement per ton of pig.

It looks as though this were an instance where by getting pretty far away from Grüner's "ideal working" we were effecting a coke economy by an unusual amount of reduction work being performed by fixed carbon. Prof. J. W. Richards has shown in his *Metallurgical Calculations*, p. 253, that "Whatever fixed carbon burns or oxidizes above the region of the tuyère, in a blast furnace, absorbs oxygen from the charge with three times the efficiency of carbon first burnt at the tuyères. . . . The ordinary furnace produces at the tuyères, in order to get heat enough to melt down the charges, *more* CO gas than is needed to abstract all the oxygen from the charge; under these conditions it is uneconomical to oxidize any carbon at all above the tuyères. The exceptional furnace, because of pure ores, small amount of slag, pure fuel, high temperature of blast, or dry blast, gets heat enough at the tuyères to melt down the charge *without* producing enough CO gas to reduce all the charges; under these conditions more or less reduction is effected by solid carbon, and with the greatest economy in quantity of carbon required in the furnace. These are conditions under which, having passed the turning point, the greater economy of fuel is attained the farther away one can get from "Grüner's ideal working." Under this explanation, in our case the credit for the result is probably due in large part to pure ores very uniformly well prepared physically and carrying a considerable quantity of granular fines exposing a large surface to reducing agents.

Returning for a moment to the case of furnaces blown by reciprocating engines, the following calculations are of interest They are based in

the first two instances on data kindly furnished me, and in the third instance on data furnished in connection with A. N. Diehl's discussion of another topic.² The first two furnaces operate largely on magnetites and the third on Lake Superior ores:

	1	2	3
Lb. coke per ton pig.....	3,083	2,500	2,256
Lb. carbon in coke.....	2,635	2,150	1,897
Less carbon to pig.....	90	90	86
Lb. carbon to be burned per ton pig...	2,545	2,060	1,811
Lb. air required if all burned to CO at tuyères, $C \times 4/3 \times 100/23$	14,753	11,942	10,498
Cu. ft. air per ton pig, lb. air $\div 0.0763$	193,355	156,513	137,588
Cu. ft. air per lb. coke, theoretical....	62.7	62.6	60.9
Cu. ft. air per lb. coke, engine rating...	67	57.6	60.8
Cu. ft. air per ton pig, engine rating....	206,561	144,000	137,164
Excess engine rating in cu. ft.....	13,206		
Deficit engine rating in cu. ft.....		12,513	424

These figures show in the first case that, by engine measurements, 13,206 cu. ft. of air more than is needed to burn all the coke per ton to CO at the tuyères is being blown, an excess sufficient to burn 210 additional pounds of coke. This case leaves no allowance for any loss of carbon whatever in the upper part of the furnace.

In the second case the rated air delivery is within 12,513 cu. ft. of the quantity required if all the carbon were burned to CO at the tuyères, leaving only 199 lb. of coke per ton of pig to be lost in the upper part of the furnace.

In the third case the rated air delivery is practically exactly the theoretical requirement if all the carbon charged as coke were burnt to CO at the tuyères. This furnace seems to lose no carbon whatever in the upper part of the furnace.

One can only conclude either that these engine ratings of air blown are misleading, or that the furnaces in question get all their coke down to the tuyères without losing any of it in transit thither either by the action of CO₂ on it or by direct reduction of oxide by solid carbon.

We next raise the question whether air delivered to a furnace in a continuous stream would have a tendency to cause different conditions within a furnace than those we are accustomed to consider produced by the air delivered in a series of pulsations. It is conceivable that these might be, less momentary lingering of the ascending gases, less time allowed them to play around the stock at any given part, and a more uninterrupted supply of gases at every point to act upon the descending stock. If there are any different conditions within the furnace traceable

² *Bulletin* No. 84, Dec., 1913, p. 2954.

to this source they would naturally tend toward increased regularity of working.

Laying aside these aspects, we are free to say that there is a uniformity in our furnace operation that is not entirely due to uniformity of stock used, but for which we incline to give large credit to the uniform work of the turbo blower. Its automatic adjustment to pressure variations is prompt and effective, and so long as the boilers produce the necessary power we are not dependent on the personal attention of an engineer in adjusting engine speeds to meet the pressure changes on the furnace. It is an important aid to the uniform work of a furnace to have uniformity of blast volume, and to get it automatically is to get it most certainly. With uniform stock supplemented by uniform blast we are able to operate without changing our quantity of air for months at a time, and with no further changes of burden than the occasional substitution of one magnetite for another, and trifling occasional changes of limestone, but maintaining a fixed ratio of ores to coke. Whether its calibration be accurate or not, it certainly gives uniform quantities at any given rating, and whether we are actually using more or less cubic feet we are using the amount required with continuous and reliable regularity.

In conclusion, we believe that the turbo blower measures the volume of air used with more accuracy than the calculations based on piston displacement in other types of blowing engines; that as a corollary to this most furnaces run on reciprocating engines are using less air than they generally figure; also we are inclined to a preference for the steady stream of air furnished by a rotary blower, and are sure that the uniformity of volume automatically delivered, whether correctly or incorrectly rated, is an important feature in securing a uniform furnace operation.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the New York meeting, February, 1914, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Apr. 1, 1914. Any discussion offered thereafter should preferably be in the form of a new paper.

The Application of Electric Motors to Shovels

BY H. W. ROGERS, SCHENECTADY, N. Y.

(New York Meeting, February, 1914)

THE first steam shovels used in this country were built by the Otis Company, of Boston, about 50 years ago, but as they were of very crude construction and rather unsuccessful only a few were built.

For possibly 10 years prior to 1884 successful steam shovels were made and used on certain classes of work, but it was not until that time that they were manufactured in quantities and began to play an important part in all classes of excavation. From that time up to the present day there have been gradual but continuous improvements on the original shovel, not only in the mechanical construction, but also in the design of boilers and engines which are best adapted to this class of service.

In proposing a change from steam to electric operation we have to deal with a steam equipment which has not only proved its worth but has probably reached its highest stage of development and efficiency. That the electric shovel is a possibility cannot be denied, as at present from 12 to 18 shovels are in operation in this country. These shovels may be divided into three classes: the friction electric, which is operated by a single constant-speed motor with friction clutches; the three or four motor direct-current equipment, and the three or four motor alternating-current equipment. It is the second and third classes that I wish to deal with, as the first class does not compare favorably with the steam shovel so far as speed is concerned, although it may be operated as cheaply.

There is probably no other class of machinery that presents a duty cycle as severe as that of the shovel, which is very short, varying from 7 to 12 sec. on the hoist, from 7 to 12 sec. on the thrust, and from 10 to 18 sec. on the swing, making a complete cycle in from 17 to 30 sec., and the motor to meet these requirements must have a sufficiently low armature inertia to permit of rapid acceleration and quick reversals under small power. It should also be a motor of rugged design, as it must be subjected to severe overloads and shocks and frequent reversals. This is especially true of the hoist motors and, to a lesser degree, of the swing motor; the thrust motor being practically stalled during the digging operation, although it may revolve or overhaul, according to conditions, and is operated at full speed only after the hoisting operation is completed.

Fig. 1 is a view of a 30-h.p. motor operating the thrust on a 65-ton electric shovel.

In the case of the hoist, considerable advantage may be gained by using two motors of small capacity instead of one large motor, as the power required for accelerating is much less. For example, assume a shovel that requires a 150-h.p., 425 rev. per minute motor for the hoisting operation; this motor requires 117 h.p. torque to bring it to speed in 1 sec., whereas if we substitute two 75-h.p., 500 rev. per minute motors in place of it, each motor requiring 32.3 h.p. torque to bring it to speed in 1 sec., or 64.6 h.p. torque to bring both motors to speed in 1 sec., there would be a saving of 45 per cent. in the power required to accelerate the motors

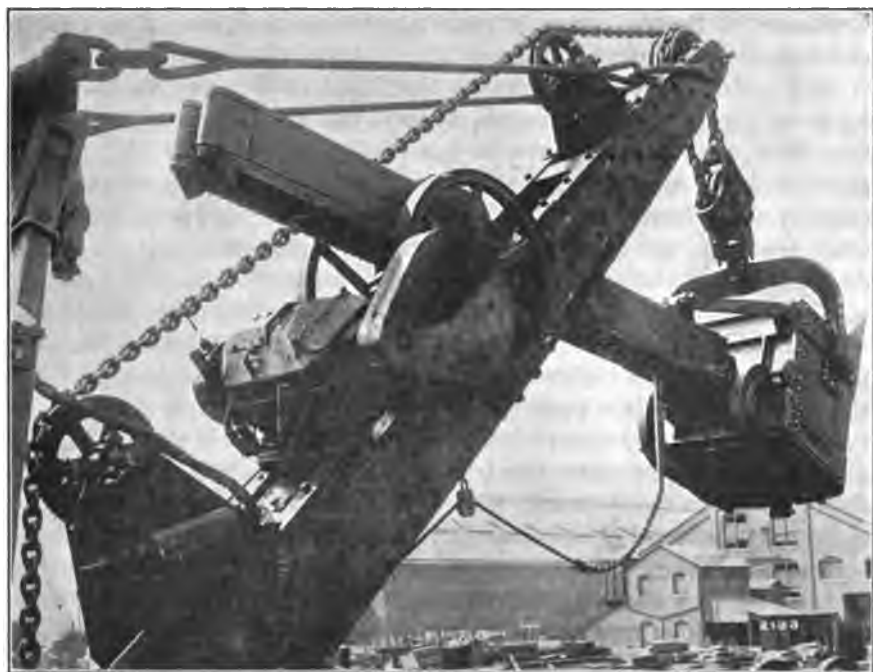


FIG. 1.—30-H.P. SERIES MOTOR AND CONTROLLER OPERATING THE THRUST ON A 65-TON ELECTRIC SHOVEL.

alone. A plan showing the best method of locating and gearing motors to hoist and swing machinery is given in Fig. 2.

Although there may be some demand for equipments to operate on direct-current circuits, the greater part will be required to operate on alternating-current circuits at 60 cycles, and the question naturally arises as to whether the direct-current series motor with motor-generator set or the alternating-current motor with transformers should be used.

This question has been the subject of considerable discussion and there still exists a difference of opinion as to whether the direct-current series motor or the slip-ring induction is best adapted to this service. As a means of comparison the accompanying curves, Fig. 3, have been plotted between speed and torque, and between speed and kilowatts input, on two 80-h.p., 500 rev. per minute, direct-current series motors operating in multiple and two 150-h.p., 450 rev. per minute, 60-cycle, slip-ring induction motors operating in multiple. These curves are based on a gear ratio of 3.31 to 1.0 on the direct-current motors and a gear ratio of 1.45 to 1.0 on the induction motors, the torque values given applying to

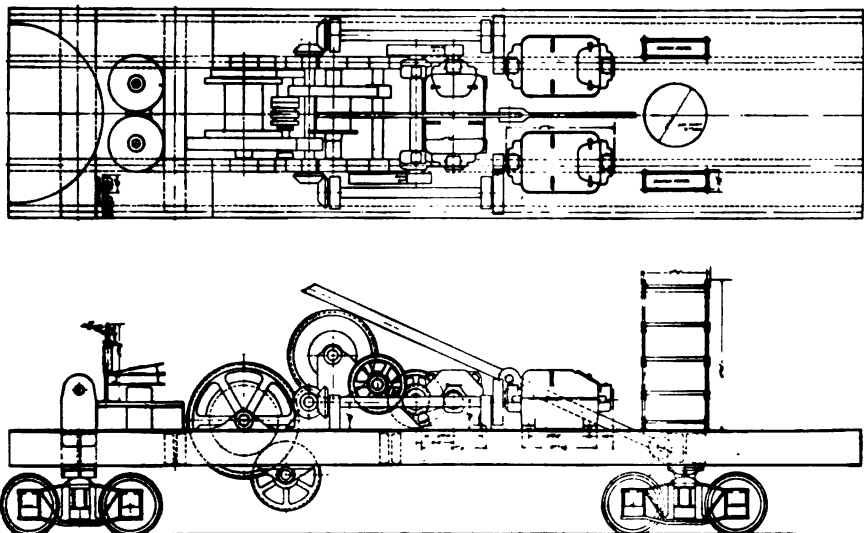


FIG. 2.—PLAN VIEW OF SHOVEL, SHOWING BEST METHOD OF LOCATING AND GEARING MOTORS TO HOIST AND SWING MACHINERY.

the back shafts, which correspond to the bull-pinion shaft on the steam engine.

In laying out an electric shovel drive there are really four things to be considered: namely, the speed at maximum torque, the speed at light load, the power required by the motor, and the gear ratio. An increase in the gear ratio results in a decrease in power at both light and heavy loads, an increase in the speed at heavy loads, and a decrease in the speed at light loads, and taking all of these variables into consideration the gear ratios given above seem to be the most satisfactory.

The direct-current series motor has the characteristics of the steam engine, in that it gives its heaviest torque on starting, speeds up under light loads, and slows down under heavy loads. It is much easier to control and requires considerably less apparatus, in so far as the control is concerned, than the alternating-current equipment. This character-

istic is clearly shown on the curve, which represents a five-point control, four of these points being used to cut out the armature resistance and the fifth to weaken the series field, which results in a very high light-load speed.

With the alternating-current slip-ring motor it is impossible to obtain the maximum torque on starting; and the light-load speed, which is very important, is limited by the synchronous speed. The only means of improving this disadvantage is to reduce the gear ratio or use a higher-speed motor, either of which methods would mean an increase in the

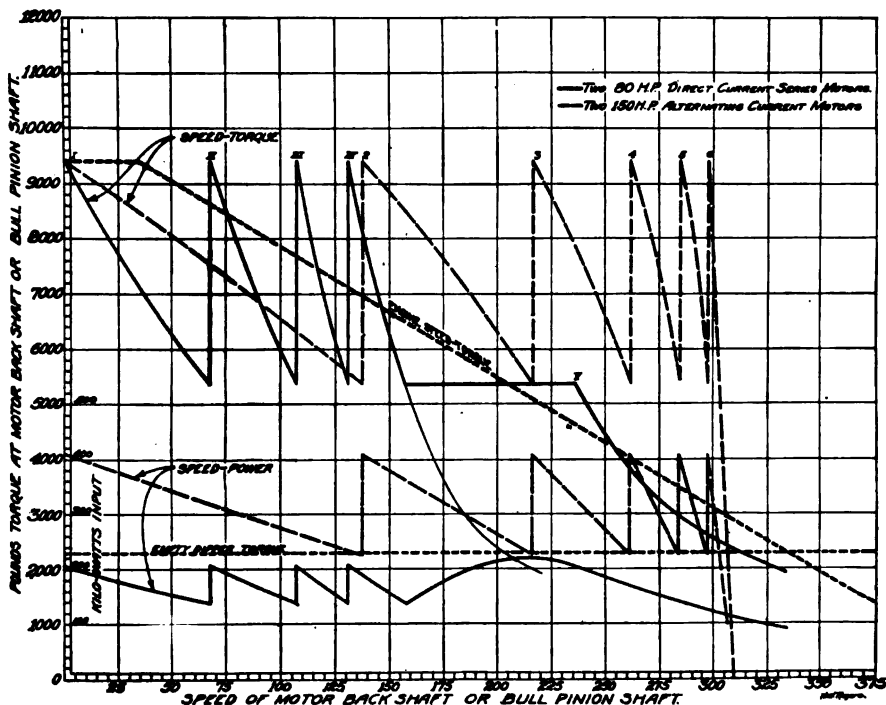


FIG. 3.—COMPARISON OF SPEED-TORQUE AND SPEED-POWER CURVES ON DIRECT-CURRENT SERIES AND ALTERNATING-CURRENT SLIP-RING MOTORS.

capacity of the motors and an increase in the inertia, which would result in an increase in the power required and a slower acceleration, both of which are undesirable. This feature will be appreciated from the following data applying to the motors used in plotting the curves.

	Total WR ¹	Diameter Rotor Inches	Per cent. Torque to bring to Speed in 1 Sec.
Two 80-h.p., 500 rev. per min.—series	444	16	43
Two 150-h.p., 450 rev. per min.—induction	2480	30	98

Under this condition the natural result is a much larger kilovolt-ampere capacity in transformers for the induction motors than kilowatt capacity of motor-generator set for the direct-current motors.

The saving in operating expense of the electric shovel over the steam shovel will depend somewhat upon the comparative cost of coal and electric power and will vary for different localities, but it should be remembered that the electrically operated shovel eliminates the fireman, the watchman, the coal passer, teaming for $\frac{1}{2}$ day, the use of water, and considerable waste. The natural increased wear and tear of parts having a transverse motion as compared with those having rotary motion and

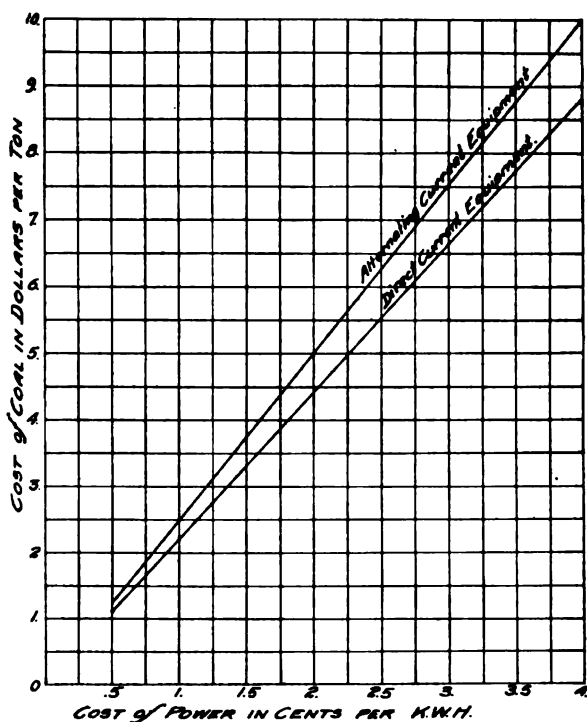


FIG. 4.—CURVE SHOWING COMPARATIVE COST OF COAL AND ELECTRIC POWER.

the elimination of boiler trouble should also be considered. Fig. 4 shows graphically the comparative cost of coal and electric power.

As an illustration consider a 120-ton shovel which is ordinarily equipped with a 5 cu. yd. dipper and has an average capacity of approximately 2,500 cu. yd. per 10-hr. day. This capacity is based on an average working time of 55 per cent. and an average dipper capacity of $3\frac{1}{2}$ cu. yd., or 75 per cent.

With a good grade of coal the steam shovel will require approximately $3\frac{1}{4}$ tons per 8-hr. shift and will make an average of two complete cycles

per minute. For the purpose of comparison, however, the maximum capacity of the shovel is taken; *i.e.*, three cycles per minute. Under these conditions either the steam or the electric shovel will have a total working time during one shift of $8 \times 60 \times 0.55 = 264$ min., during which time it will make $264 \times 3 = 792$ complete cycles, and will handle $792 \times 3\frac{1}{2} = 2,970$ cu. yd. of material.

The direct-current shovel would be equipped with two 80-h.p., 500 rev. per minute, 230-volt series motors on the hoist, one 40-h.p., 550 rev. per minute, 230-volt series motor on the swing, one 60-h.p., 550 rev. per minute, 230-volt series motor on the thrust, and one 150-kw., 900 rev. per minute, 250-volt direct-current generator direct connected to a 225-h.p., 900 rev. per minute, 2,200-volt induction motor, with four-point reversible automatic control on each motor.

The estimated power consumption during each cycle will be as follows:

	Kw-seconds
Hoisting.....	1,379
Swinging.	522
Crowding.....	547
Total.....	2,448 = 0.68 kw-hr.

$792 \times 0.68 = 539$ kw-hr. input to the motors per 8-hr. shift, or, taking into account the efficiency of the motor-generator set, 657 kw-hr. per 8-hr. shift.

As the shovel is working only 55 per cent. of the time, the motor-generator set will be running light 45 per cent. of the time, or $8 \times 60 \times 0.45 = 216$ min.

The power consumption on the set when running light will be approximately 16.77 kw.

$$\frac{216 \times 16.77}{60} = 60.4 \text{ kw-hr. loss per 8-hr. shift.}$$

$657 + 60.4 = 717.4$ kw-hr. total power consumption per 8-hr. shift when working under the maximum cycle.

$$\frac{717.4}{2,970} = 0.241 \text{ kw-hr. per cubic yard excavated.}$$

The alternating-current shovel would be equipped with two 150-h.p., 450 rev. per minute, 440-volt motors on the hoist, one 50-h.p., 720 rev. per minute, 440-volt motor on the swing, one 75-h.p., 600 rev. per min., 440-volt motor on the thrust, and three 125 kilovolt-ampere, 2,200-480-volt transformers, with five-point reversible automatic control on each motor.

The estimated power consumption during each cycle will be as follows:

	Kw-seconds
Hoisting.....	2,040
Swinging.....	759
Crowding.....	750

Total..... 3,549 = 0.987 kw-hr.

$792 \times 0.987 = 782$ kw-hr. input to the motors per 8-hr. shift, or,
taking into account the efficiency of the transformers, 796 kw-hr.
per 8-hr. shift.

The no-load losses on the transformers will be approximately

$$\frac{216 \times 3.6}{60} = 13.0 \text{ kw-hr. loss per 8-hr. shift.}$$

$796 + 13 = 809.0$ kw-hr. total per 8-hr. shift.

$$\frac{809}{2,970} = 0.273 \text{ kw-hr. per cubic yard excavated.}$$

Labor per shift	Steam	Electric
Shovel runner.....	\$6.00	\$6.00
Craneman.....	4.00	4.00
Fireman.....	2.50	.....
Six pitmen at \$1.75.....	10.50	10.50
One watchman.....	1.75	.....
One coal passer.....	1.50	.....
Teaming ($\frac{1}{2}$ day).....	2.50	.....
Oil and waste.....	1.50	.75
Total.....	\$30.25	\$21.25
Saving, electric over steam.....	21.25	

\$9.00 per shift.

For convenience in comparing the costs of operation on steam and electric shovels the costs are all reduced to a day basis.

	Steam	Electric Direct Current	Electric Equivalent Alternating Current
Interest at 6 per cent.....	\$5.20	\$7.75	\$10.85
Depreciation at $4\frac{1}{2}$ per cent.	4.03	6.00	8.43
Repairs at 10 per cent.....	8.66	.....	.....
Repairs at 6 per cent.....	.....	7.75	10.85
Labor per shift.....	30.25	21.25	21.25
Total cost per shift.....	\$48.14	\$42.75	\$51.38

It has been assumed that, owing to weather conditions, delays, etc., the shovel working year consists of 150 days and the above figures are based on this assumption; also that the shovel is only working one shift a day.

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The Use of Petroleum in Dust Prevention and Road Preservation

BY L. W. PAGE,* WASHINGTON, D. C.

(New York Meeting, February, 1914)

PREVIOUS to the introduction of the motor vehicle the broken stone or macadam road met the conditions of rural horse-drawn traffic better than any other type of road, but under fast motor traffic it has been proved to be quite unsatisfactory, and necessitates high maintenance charges. Such a road depends for its success upon the fact that the rock dust fills the voids between the stones and acts as a cement or binder. Under ideal conditions it should be constructed of rock so suited to the volume and character of horse traffic that only enough fine dust is worn from the stones of which the road is composed to take the place of that carried off by wind and rain; and when these conditions are met, the fine dust resulting from the wear of traffic forms with the stone a smooth, impervious shell, shedding the surface water and protecting the foundation. With increase in the number and speed of motor vehicles, however, it was soon found that the cost of maintenance also increased, until at the present day highway engineers consider the old method of constructing and maintaining broken-stone roads increasingly inadequate, and are introducing every known type of binding material other than rock dust to cement the stone together. Among the most prominent types of products in use are those produced from our various petroleum.

That the value of modern methods of road preservation was appreciated in this country much earlier than we have been accustomed to believe is demonstrated by the recent revival of an old patent which was granted to one John Martineau, of Elbridge, N. Y., in 1834. Petroleum had, of course, not been discovered at that time, but he claims as his invention and improvement "The application of tar, turpentine, or any of that class of tenacious, cohesive substances, reduced before use to a fluid state, and that state used as a cement, to apply to, and combine with sand, gravel, pebbles, and pulverized stone, such as is used for a McAdam road, or cobble stone, the interstices of coarser material being in all cases filled, as well as may be, with sand and gravel and cemented with tar or turpentine, to form the wearing face or surface of streets,

* Non-member.

roads, etc., in the manner described in this specification." The specifications are, moreover, of rare interest in that they forestall our modern ideas of dense mixture by specifying "Whatever kind or variety of materials are selected in any particular case, the whole should be rendered as compact and uniform as possible. If coarse materials enter into the composition in any case, finer materials should be combined therewith to fill the vacancies, render the mass solid and compact, and the upper surface smooth and even." A general type of distributor is also described which embodies the principal features, excepting high pressure, of machines in use to-day.

The beneficial effect of oil on roads was observed in the early days of the development of the Pennsylvania oil fields. Through tracking and dropping, appreciable quantities of oil naturally came upon the surface of the various roads communicating between the wells, and although no systematic use of the observation was made, it was noted that a denser, more compact surface was formed, with the elimination of dust.

However, these early observations never came into prominence and it may be said that experiments in California were the forerunners of our recent developments in the application of oil to roads. In 1894 crude Summerland oil was applied to the earth roads of Santa Barbara county, and the results proved so successful that the practice rapidly spread throughout the State. The character of the native crude oil together with peculiar soil and climatic conditions favored the success of this type of improvement in the locality where it originated, and it was not long before the fame of the California oiled road became widely known. This naturally led to similar experiments in the East, but these met with mixed success and failure owing to the widely varying character of the available oils and different local conditions.

The California oils are, as a whole, distinctly asphaltic in their general character, consisting essentially of the unstable polycyclic polymethylene hydrocarbons which characterize the native asphalts. They possess decided adhesive properties and the property of rapidly hardening or "setting up" upon exposure to atmospheric influences. The oils from the other fields of the United States vary from those of the Appalachian and Ohio-Indiana fields, which are composed largely of saturated paraffin hydrocarbons, to those of the Gulf field, which contain a larger percentage of unsaturated hydrocarbons and are frequently characterized as semi-asphaltic. The former are of a naturally greasy consistency and cannot be made to develop any adhesive properties by refining processes. They possess a certain value as dust-layers, where the purpose is simply to hold down by capillarity the dust which has already been created upon the road surface. Their effect is temporary, and the necessary frequency of application is dependent on local conditions. The same general statement is true of most of the crude oils from other fields, excepting

California, although the so-called semi-asphaltic oils, on account of the nature of their hydrocarbons, can be made to yield satisfactory products for surface treatment and road construction.

During the past two or three years two hitherto unknown types of petroleum have come into prominence—the Trinidad and the Mexican oils. The more fluid grades of both are similar in that they consist of a relatively large amount of adhesive asphaltic base held in solution by natural solvents of low boiling point. Both are rich in unsaturated hydrocarbons, and the essential differences between them appear to rest in the fact that the Mexican petroleums have a higher sulphur content than those from Trinidad, and yield appreciable quantities of paraffin scale, which is not found in the Trinidad oils. Both, however, when of proper consistency for the work in question, have yielded satisfactory results when properly applied.

Through processes of experiment and development two general methods of dust prevention and road preservation have resulted:

- (1) The treatment of the road surface with substances capable of holding down the dust present and of laying dust brought in from outside sources.

- (2) The internal treatment of roads with binders capable of reducing road wear and disintegration and, therefore, dust formation from the road material proper.

The first method, which is generally spoken of as surface treatment, may really be further subdivided with regard to the class of material used and the form of treatment pursued. The purpose is usually accomplished with fluid petroleum products of proper viscosity for hot or cold application, as the case may be. These products are usually classified as temporary and semi-permanent binders, according to the results they will yield. Under the first classification we include those products whose principal function is to hold dust *in situ*, largely by capillarity. They need not necessarily possess any pronounced binding value, and must be applied several times during a season in order to accomplish their purpose satisfactorily. They are generally applied without any extensive preparatory cleaning of the surface, and their only preservative action results from the fact that they hold upon the surface a loose pad of dust and oil. The lighter grades of our native crude petroleums which are capable of being applied cold will serve the purpose of temporary binders or dust palliatives, and some of the high-boiling distillates have been used with satisfaction. Emulsions of residual petroleums with alkaline soap solutions have also been extensively used in the treatment of park roads, for the reason that they are readily miscible with water and may be cheaply and efficiently applied from an ordinary sprinkling wagon. Emulsions, however, to be successful, should be of such character that they will remain emulsified when mixed with

water, and after application will evaporate in such form that they may not be readily washed out by rain.

Semi-permanent binders constitute the class of petroleum products which will yield efficient results on a single application or less per season, and their use involves real surface treatment as now generally understood. They should be applied to a thoroughly cleaned road surface for the purpose of forming a wearing surface or mat with the rock screenings or gravel with which the application of oil is covered. A treatment of this character acts not only as a dust preventive in that it holds to some extent extraneous dust which may be brought on to the surface, but also as a road preservative in that it takes the wear which would otherwise come upon the road material proper. The cost of maintaining a surface mat of this character is dependent upon climatic and traffic conditions, but, as a general proposition, it may be said that it gives best surface under traffic in which automobiles are the predominating class. The Office of Public Roads is at present watching with interest a series of experiments in which 9 miles of newly resurfaced limestone macadam was treated in sections with seven different surfacing materials. Both hot and cold applications were made with three varieties of tar products and four of petroleum products. Traffic censuses are being regularly made and accurate maintenance data kept with a view to determining the relative economy of the several experiments.

The results of observations to date would indicate that a petroleum product to prove of value as a semi-permanent binder in surface treatment should possess decided adhesive qualities or should at least develop such properties in the residue from the standard volatilization test at 163° C. These qualities are, of course, most pronounced in petroleum products which we have classified as asphaltic. For cold treatment, those oils, either natural or artificially prepared, which consist of a light solvent carrying a sufficient quantity of viscous adhesive base, have met with much favor of late. Such oils are of a consistency to be readily applied without heating, but owing to the volatility of the solvent they possess the characteristic of "setting up" with fair rapidity.

For hot surface treatment the heavy residuals from asphaltic oils or from those semi-asphaltic petroleum products which contain a sufficient amount of unsaturated hydrocarbons to yield products of well-defined binding quantities prove best. Eastern petroleum products or those from other localities which are rich in paraffin hydrocarbons are not adapted to the preparation of semi-permanent binders.

The second method or internal treatment for road preservatives is generally accomplished by one of two methods.

In the penetration method, the best practice is to place upon the subgrade, prepared as for ordinary macadam work, a foundation course of No. 1 crushed stone to the desired depth. This is well rolled, with the

addition if necessary of sand or screenings to thoroughly bond the course, care being taken that there is no excess of fine material which will prevent the wearing course from keying into the foundation. The road is then rolled until absolutely firm, more screenings being applied if necessary to take the place of those worked into the foundation. The wearing course of No. 2 crushed stone, clean and free from dust and screenings, is then applied to a finished depth of 2 or 3 in., and this course lightly rolled. The hot bitumen is next poured or sprayed upon the road at the rate of about $1\frac{1}{2}$ gal. per square yard, after which a light coat of clean $\frac{1}{2}$ -in. stone chips, free from dust, is applied and the road well rolled. A seal coat of bitumen is then painted upon the surface at the rate of from $\frac{1}{2}$ to $\frac{3}{4}$ gal. per square yard, after which screenings are applied and rolled in until the road is smooth and firm.

In general, the mixing method is conducted as follows: Upon a foundation course of crushed stone, prepared in the same manner as for the penetration method, a mixture of crushed stone and bitumen is laid to a finished depth of from 2 to 3 in. and rolled, with the addition of screenings. A paint coat of bitumen is then applied and the road finished off in the manner previously described. The mixture of stone and bitumen may be prepared either by manual labor or by machinery, preferably the latter, and the mineral aggregate may be graded in any approved manner.

Both of these forms of wearing surfaces are sometimes laid over a concrete base, and the mixing method is frequently varied by carefully grading the aggregate or adding a given portion of sand to the stone with a view to forming a denser surface.

For construction work of the above character we use what we are accustomed to term permanent binders, which include the heavy semi-solids or asphalts prepared from petroleum. They are preferably obtained from asphaltic petroleums either by direct distillation or by distillation with air agitation. By the latter method, when properly carried out, it is possible to obtain a product of given consistency at a lower distillation temperature than would otherwise be the case. Certain grades of semi-asphaltic petroleums from our middle Western and Gulf fields yield satisfactory binders, which are sometimes reinforced by the addition of gilsonite. The proper consistency of a permanent binder for any, given piece of work will be dependent upon the location of the project climatic and traffic conditions, and the nature and grading of the aggregate, so that no one standard grade can be recommended for construction work in general. And even the general classification of binders, as above given for use in the treatment of broken stone roads, may vary somewhat where they are to be used in conjunction with certain types of road rock. In recent experimental work in Florida, under the supervision of the Office of Public Roads, an effort was made to develop a

method of bituminous construction in which the soft, powdery, and absorbent native coralline rock could be used. What we would customarily designate as a permanent binder would not adhere to this material, but excellent results were obtained by the penetration method in the use of a viscous fluid product that would ordinarily be classified as suitable for surface treatment only.

The author has attempted to cover in a short paper the principal types of petroleum products which are used throughout the United States for the purposes of dust prevention and road preservation, the general methods by which they are applied, and a few of the desiderata which a petroleum product should possess when selected for a given purpose. The finer details of manufacture, selection, and use all offer subjects for much more extended discussion than the present occasion would necessitate or permit.

TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS
[SUBJECT TO REVISION]

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the New York meeting, February, 1914, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 20 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Apr. 1, 1914. Any discussion offered thereafter should preferably be in the form of a new paper.

Use of Electricity at the Penn and Republic Iron Mines, Michigan*

BY WILLIAM KELLY AND F. H. ARMSTRONG, VULCAN, MICH.

(New York Meeting, February, 1914)

THE object of this paper is to describe the electric equipment at the iron-ore mines of Penn Iron Mining Co., Vulcan, Mich. and of Republic Iron Co., Republic, Mich.; to give the results of tests; and to discuss the methods in use from an operating as well as from an efficiency standpoint.

Electricity was introduced at the Penn mines for pumping, hoisting, and compressing air in the spring of 1907, upon the completion of a hydro-electric plant built by that company on the Menominee river about 4 miles from the mines. This plant was described in a paper¹ presented before the Lake Superior Mining Institute. A paper² presented at a meeting of the same Institute describes some of the operating features, and the safety devices of the electric hoist at the Curry shaft were briefly described in the *Proceedings* of the First Co-operative Safety Congress held under the auspices of the Association of Iron and Steel Electrical Engineers at Milwaukee, Wis., Sept. 30 to Oct. 5, 1912.

GENERATING POWER PLANTS

After the success of electrical operation was assured, a second set of water wheels and generator was installed at the falls, for which provision had been made in the original design and in the construction of the foundations, and later three additional wires were added to the main transmission line, doubling its capacity and reducing the line loss.

The general conditions of this installation are particularly favorable for hydro-electric operation. In the neighborhood of three-fourths of the power used is for mine pumping, which in the main is regular and continuous. For air compressing, power is used for about 18 hr. a day for five days, and 9 hr. for one day in the week, though occasionally when shaft sinking is going on a very small amount of compressed air may be

* To be presented also, by mutual agreement, at the meeting of the Lake Superior Mining Institute, August, 1914.

¹ T. W. Orbison and F. H. Armstrong, *Proceedings of the Lake Superior Mining Institute*, vol. xiii, pp. 153-151 1908.

² Frank H. Armstrong, *idem*, vol. xvi, pp. 244-250 1911.

required continuously. Hoisting and surface tramping, which are intermittent, require only about 6 per cent. of the power used. The pond above the falls covers an area of about 450 acres and the head is 25 ft. There is, therefore, an ample quantity of water to take care of the ordinary irregularities of consumption without much change in the head, but on the other hand it does not supply any extended storage, as if the flow from above was entirely cut off the drawing down of 1 ft. would furnish water to supply the power requirements for only a little over 4 hr.

The power requirements of the mines, though somewhat variable, have been averaging about 2,400 h.p. The Menominee river furnishes this amount of power at what may be considered the normal stage. In dry seasons the water power has to be supplemented, and therefore a 1,500-kw. steam turbo-generator has been installed at the principal mine. This is sufficient in itself to take care of the pumping, if for any reason the hydro-electric plant should be out of commission. As a matter of fact, this has occurred without control only four times in six years, three times on account of anchor ice, not over 8 hr. at either time, and once for 3 hr. on account of a break in the transmission line due to a faulty disconnector. The protection against anchor ice is the length of the pond, which is about 5 miles to the next rapids above. As soon as this pond freezes over the anchor ice formed above does not come through. The three experiences with anchor ice were on days late in the fall before the pond had frozen over, when the temperature fell much below the freezing point and there was a high wind.

At the falls the generating units are of 1,500 and 2,000 kw., 6,600 volts, and are run singly or together according to the mine requirements and the quantity of water available. During the years 1911, 1912 and the first half of 1913, there was generated at the falls 37,502,160 kw-hr. at a cost, including taxes, of 0.083 c. per kilowatt-hour. The steam plant generated 1,670,700 kw-hr. at a cost, including stand-by expenses, of 1.821 c. per kilowatt-hour. The average cost of power for operating was 0.157 c. per kilowatt-hour. Depreciation for a 20-year period and interest at 5 per cent. add 0.182 c., making the total cost, including operating, taxes, and depreciation, 0.339 c. per kilowatt-hour.

At Republic the small water power is used entirely for compressing air. Electricity is used for the pumping, one surface tram, the crusher plant, and the shops. The principal generating unit is a mixed-pressure steam turbo-generator which runs on the exhaust steam of the hoisting engines supplemented by live steam. The exhaust steam is passed through a regenerator in order to distribute its use to as great an extent as possible during intermissions of hoisting. The successful utilization of intermittent supplies of low-pressure steam depends very largely on having the regenerator capacity of ample size. The steam turbine runs at 9,000 rev. per minute. Live steam is automatically supplied to fill any deficien-

cies in the amount of exhaust steam available. There is an independent condenser which produces a vacuum of 27 in. Geared to the shaft of the steam turbine are two electric generators of a combined capacity of 150 kw., which run at 900 rev. per minute. These are to have fly wheels on the shafts so as to eliminate the peaks and reduce the heavy voltage fluctuations. Each wheel is 52 in. in diameter by 10 in. thick and weighs something over 5,000 lb. The speed of the turbine when using live steam is $3\frac{1}{2}$ per cent. less than when using exhaust. These fly wheels will give, for this reduction in speed, 525 h.p.-sec. There is a back pressure on the hoisting engines varying from a maximum of 4 lb. to a slight vacuum. As close as can be figured, this turbine is furnishing a kilowatt-hour for a fuel cost of 0.15 c.

ELECTRIC PUMPS

At the time when the original installation at Vulcan was under consideration, centrifugal pumps for high heads had not given good satisfaction in this country. There had been difficulties with thrust bearings and considerable doubt about continuous efficiencies. The correctness of the general mechanical principle of attaching a centrifugal pump directly to a high-speed motor was recognized. It was decided, therefore, to place the order for the main pumping units of centrifugal design under specifications to cover the principal requirements. In brief, these were for three units, each with an induction motor for 2,200 volts, 450 h.p., three-phase, alternating current, and a centrifugal pump in eight stages, four on each side of the motor, all on the same shaft, with a marine thrust bearing at each end, for a capacity of 900 gal. per minute at a speed of 1,200 rev. per minute, with suction lift of 20 ft. and discharge head including friction of 1,275 ft., with a combined efficiency of motor and pump of 63 per cent. Two of these units were put in at the West Vulcan C shaft and one at the East Vulcan No. 4 shaft. A view of the two pumps at West Vulcan in the pump station 1,200 ft. below the surface is shown in Fig. 1.

When the pumps were started they fell short of the guaranteed efficiency; there was trouble from heat in the thrust bearings in starting, and rapid wear of the protecting sleeves about the shaft in the high-pressure stuffing boxes. The principal changes were in closing some holes in the impellers that had been made with the expectation that they would equalize the thrust movement; in substituting for the marine thrust bearing a hydraulic thrust ring against which the pressure of water in the column pipe is automatically applied by a slight thrust movement of the shaft; in some alterations to make it easier to change the wearing sleeves on the shaft; and in experimenting with different kinds of packing. The result of this work was the raising of the efficiency to the required standard, the elimination of all thrust trouble, and a reduction of the

wear caused by the packing in the high-pressure stuffing boxes to very moderate proportions. Subsequently some further improvements were made.

Multi-stage centrifugal pumps consist of impellers attached to the shaft and stationary diffusion rings. The water enters an impeller near the shaft and issues with great velocity from its periphery. It then passes in a spiral direction through the passages of a diffusion ring to the inlet of the succeeding impeller or from the last impeller to the outlet. The expanding passageways for the water through the diffusion ring convert

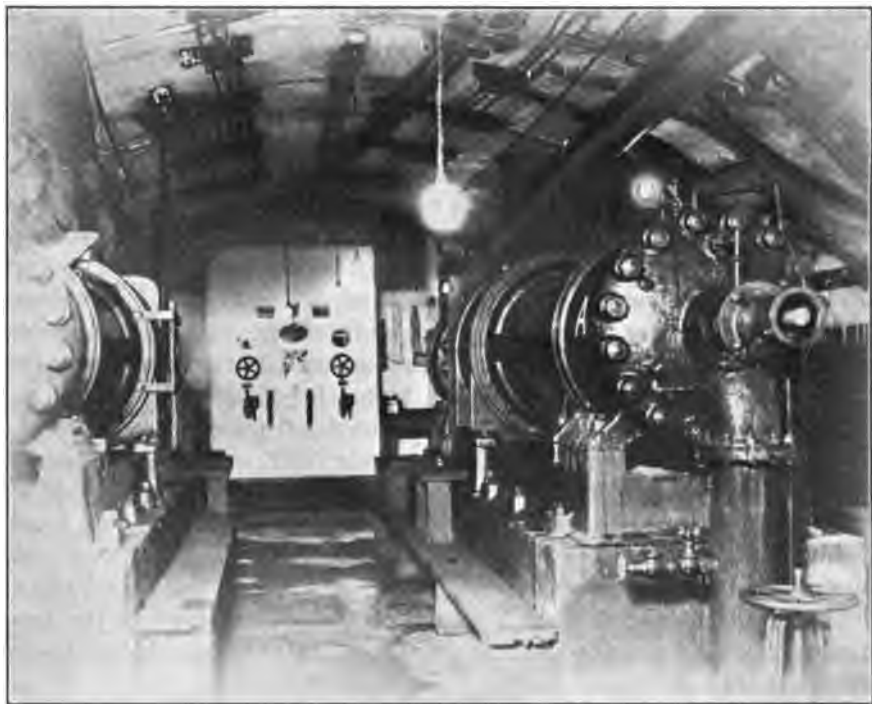


FIG. 1.—PUMP STATION AT WEST VULCAN.

the velocity into pressure. The efficiency of a centrifugal pump depends principally on the shape and size of the impellers, the internal leakages, and the friction in the water passages.

The three original centrifugal pumps are made with a solid casing and the impellers and the diffusion rings are drawn out through the end of the casing. In the pumps installed since there is no casing, but the stationary parts of each stage are held together by large through bolts. None of the pumps have casings divided horizontally, which plan introduces unfavorable joints and necessitates disconnecting and lifting out the shaft and

impellers. Without the horizontal joint the diffusion rings and impellers are very easily drawn out endways without disturbing the shaft. It takes about 4 hr. to take a pump of four stages apart and put it together again.

The experience of several years shows that there is very little wear in the interior or on the periphery of the impellers, or in the water passages leading from one impeller to another. The principal wear and the occasion of greatest loss in efficiency is between the impellers and the diffusion rings. Originally, the contact faces were quite narrow, only

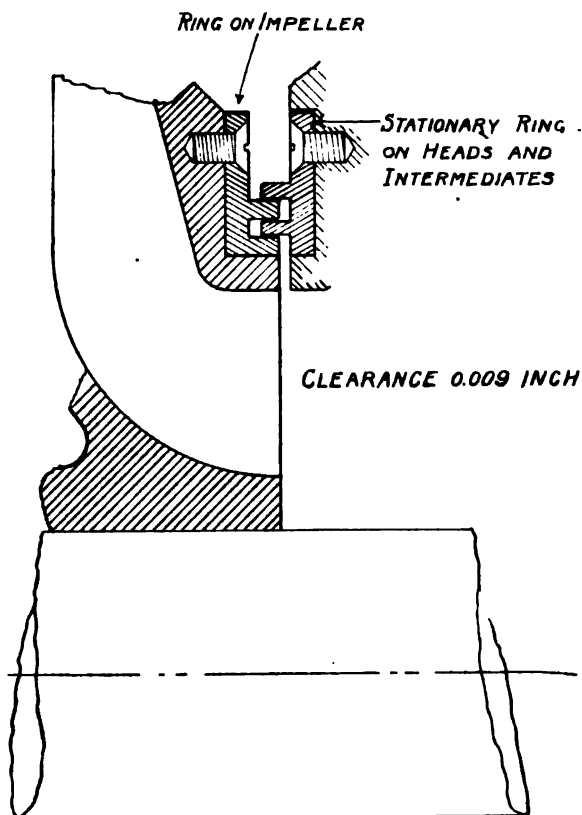


FIG. 2.—LABYRINTH RINGS TO DECREASE LEAKAGE.

$\frac{1}{8}$ in. They have since been made $1\frac{7}{8}$ in. and the tendency to leak has been decreased by using labyrinth rings, as shown in Fig. 2.

In later installations the hydraulic thrust ring was supplied with oil from a separate small motor-driven plunger pump. When oil was lacking it was found that water answered equally well. The advantage of having pressure independent of the water column is because the greatest tendency to thrust is on starting before the impellers become balanced, as they are when under the full head, because at the time of starting the column pipe

may not supply the requisite or perhaps any pressure, and also because the independent pump gives a constant quantity at a variable pressure depending upon the thrust.

The main stuffing boxes were originally packed with a solid metallic packing, but, as that did not prove satisfactory, soft metallic packing and several kinds of special packings were tried in succession, but finally practice has settled down to a good grade of square braided hemp packing. The leakage is naturally greatest through the stuffing box on the discharge end of the pump, where there is the full pressure of 552 lb. to the square inch. As the shaft has only a rotary motion, when the packing is tightened up there is nothing to distribute the pressure applied upon the outside ring of packing to the other rings, as a shaft with motion lengthways helps to do, and consequently the outside ring is apt to be pressed so tight that it wears a groove in the shaft or the protecting sleeve about the shaft. No attempt is made to lubricate the packing. The shaft is protected from this wear in the stuffing boxes by removable sleeves. It takes only 2 hr. to replace a sleeve. The replacing of the sleeves has been the greatest source of delay of a mechanical nature, but the aggregate of the delays is very small. At the East Vulcan mine, where for nearly three years there was only one electric centrifugal pump, and it was run as nearly continuously as possible, the total delays amounted to only 346 hr. in 33 months, or less than $1\frac{1}{2}$ per cent. of the time

Occasionally the discharge of the pump has fallen off, due to chips or refuse in the suction end of the pump. This is guarded against as much as possible by having duplicate wire screens in the suction tank, so that all the water from the mine has to pass through a screen. The screens are in duplicate, so that there may always be one in place when the other is raised for cleaning. In these mines it has been found that the best protection against grit in the water is to be had from good ditches which keep the water in the drifts below the traveling road. The internal wear of the water passages due to grit has been exceedingly small. The water is free from acid and without corrosive effect. The internal construction of these pumps is simplicity itself, and their dependability is much greater, and the time and cost of repairs much less, than with the triple-expansion steam pumps which the centrifugals displaced.

Approximate figures on the maintenance for one year of four centrifugal pumps as compared to four triple-expansion steam pumps doing practically the same duty are as follows:

	Centrifugal	Steam
Shop labor.....	\$717	\$760
Labor on pumps.....	690	590
Supplies.....	503	2,021
	\$1,910	\$3,371

The motors of these pumps have wound rotors with a device for short circuiting the secondary current and relieving the brushes from wear by lifting them from the rings. These pumps were rated at 900 gal. per minute and that was about the quantity of water that they handled at first. Soon after the quantity to be pumped increased to 1,100 gal. per minute. This was too much for one pump and not enough for two, so that it was necessary to start and stop one pump frequently. As this quantity of water continued for some time, it was found that by increasing the speed of the generators at the falls from 60 to 62½ cycles per second, the pumps were each capable of handling from 1,200 to 1,300 gal. per minute. This overloaded the motors, and after running for a considerable time it was found that the insulation had been baked until it was brittle. This made trouble when it became necessary to repair the windings. A dropping off in efficiency will also overload the motor, so that it is well to have centrifugal-pump motors of a larger size than the specified head and quantities under normal conditions call for.

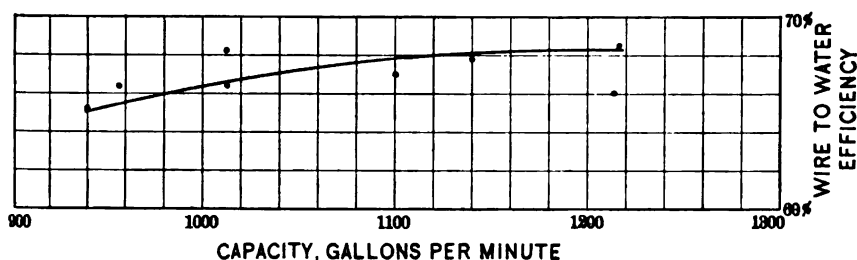


FIG. 3.—EFFICIENCY CURVE OF 8-IN. EIGHT-STAGE CENTRIFUGAL PUMP.

Fig. 3 shows an approximate curve of efficiency based on eight tests at different quantities on a pump when in first-class condition. During these tests the unit was being run at 1,235 rev. per minute and the quantity was varied by manipulating a valve on the suction.

In order to test the efficiency of the pumps it was necessary to measure the water. At first, this was done on surface, by means of both a tank with knife-edge orifice and a weir. Permanent concrete tanks were later installed at both East Vulcan and West Vulcan so as to obtain a continuous record of the amount of water pumped. One of these tanks is shown in Fig. 4. There is a division wall in it which is pierced with a great many 2-in. holes. The water from the mine flows into the back part of the tank and through the holes in the division wall into the front part of the tank. This breaks up the flow of water and prevents "velocity of approach" to the orifice. In the front wall of the tank there is a plate of steel with a circular knife-edge opening of exact size.

The quantity of water that flows through the orifice depends on the head above the center of the orifice. The head is recorded on a recording

water-level gauge and tables for each orifice show the gallons per minute corresponding to each tenth of a foot of head. One of the charts is shown in Fig. 5. This chart was used in connection with an orifice having a diameter of 7 in. and shows an average for the week of about 894 gal. per minute. When the pumping is irregular the average is ascertained by the use of a planimeter for circular charts. On this chart it can be seen that the pumps were stopped for a few minutes three times during the week. The charts are changed Sundays at noon. Orifices of different sizes are used when the quantity of water changes, so as to keep the water at somewhere between 2 and 4 ft. above the center. With these permanent

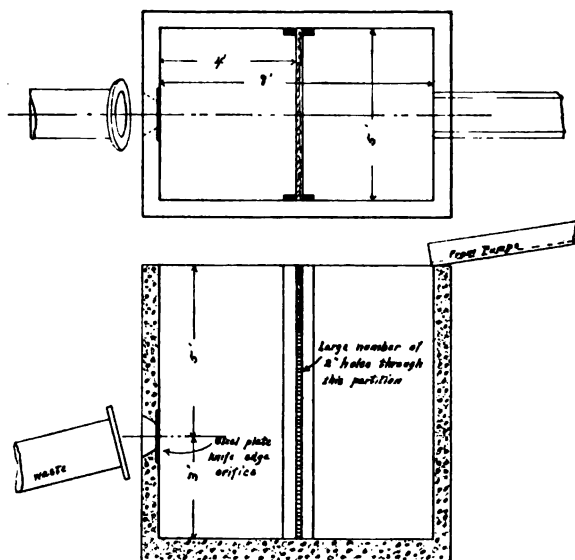


FIG. 4.—MEASURING TANK.

measuring tanks and suitable electrical instruments a test of efficiency becomes a very simple matter.

At the Brier Hill shaft, where there are only from 30 to 40 gal. per minute, and a depth of 900 ft., there is a motor-driven reciprocating, horizontal, plunger pump, of 125 gal. per minute capacity, which on Sundays and holidays may be operated from the hoist house on surface, the high- and low-water mark in the sump being provided with an electric signaling device to the hoist house.

At the Republic mine, for pumping from a depth of 1,150 ft. a motor-driven triplex plunger pump of 95 gal. per minute and a motor-driven horizontal duplex plunger pump of 125 gal. per minute are used, but at that point the maximum water is only 150 gal. per minute, with an average of about 50 gal. At other points where the quantities are moder-

ate and intermittent operation is not objectionable, motor-driven plunger pumps are used.

In the smaller sizes centrifugal pumps are inefficient, but the efficiency increases with the size. Pumps of 600 to 1,200 gal. a minute can be easily maintained at an efficiency of 55 to 65 per cent., measured from the

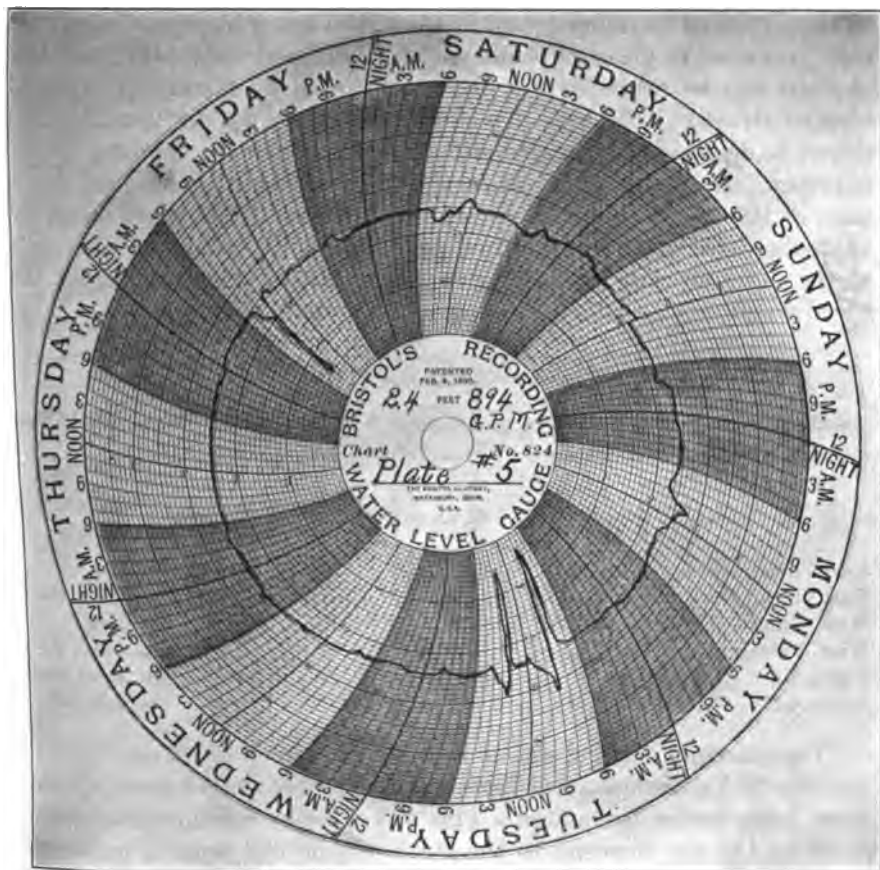


FIG. 5.—CHART FROM RECORDING WATER-LEVEL GAUGE.

power delivered to the motors to the water at the top of the shaft, while pumps of larger capacity will undoubtedly give higher efficiencies.

One of the great advantages of centrifugal pumps is that the quantity of water can be regulated within comparatively wide limits by simply opening and closing a valve on either the suction or the discharge pipe, preferably the former, with but slight variation in the efficiency. A reciprocating pump driven by an induction motor, on the other hand, must run at a constant speed. Mechanical devices to change the speed

of the pump or the quantity of water per stroke are necessarily complicated. The common practice for decreasing the quantity is to use a by-pass on the discharge column, allowing a portion of the water to return to the sump. This of course is directly at the expense of efficiency. Intermittent pumping necessitates adequate sump capacity. It may be generally said that a reciprocating pump driven by an induction motor is especially suited to pump a certain amount of water against a head that may be varied at pleasure, while with a centrifugal pump the quantity of water can be regulated but the head cannot be materially changed without structural changes. To effect the latter end a centrifugal pump should be designed for changing either the number or the diameter of the impellers. High-pressure centrifugal pumps are usually designed for a head of 100 to 150 ft. for each stage or impeller. The speed must be approximately 1,200 or 1,800 rev. per minute with a six- or four-pole motor and a 60-cycle alternating current. With a 25-cycle current the speed would not be sufficient, except with a two-pole motor.

ELECTRIC HOISTS

Before the introduction of electricity, hoisting at the Penn mines was done at five shafts with steam hoists of the following types:

Shaft	No. of Drums	Diameter feet	Geared	Position of Drums
East Vulcan No. 4.....	2	10	Yes	Tandem
East Vulcan No. 3.....	2	.....	Yes	On same shaft
West Vulcan C.....	2	12	Yes	Tandem
West Vulcan C.....	2	12	No	On same shaft
Curry No. 1.....	2	6	Yes	On same shaft
Norway No. 10.....	2	5	Yes	On same shaft

The principal hoisting was at East Vulcan No. 4 and West Vulcan C shafts. The geared plants at these two points were altered so as to permit their being driven by motors. This was done by extending the pinion shaft on the side opposite to the steam engine and putting on the extended shaft a large rope wheel, which was driven by an American system rope drive from a small rope wheel on the shaft of the motor. On the other side the connecting rod of the steam engine was disconnected. This arrangement is illustrated in Fig. 6. The method of operating is to start the motor, rope wheels, gear wheels, and drum shafts and when these are up to speed gradually to apply the clutch of the drum, thus starting the skip or cage and quickly accelerating it. This had always been the practice in starting with steam except that with the rope wheels and motor the fly wheel effect is greater.

At the same time the East Vulcan No. 3 hoist, which was used very intermittently and principally for depths of only 250 ft., was run by

compressed air generated by a motor-driven compressor. As the work of this hoist has increased a motor and belt have been substituted for the engine, as shown in Fig. 7. The same change was made with the Norway hoist. The first-motion steam hoist at West Vulcan has been dispensed with. The Curry hoist was formerly run by steam from the saw mill. This hoist was too small for the work and has been replaced by a new

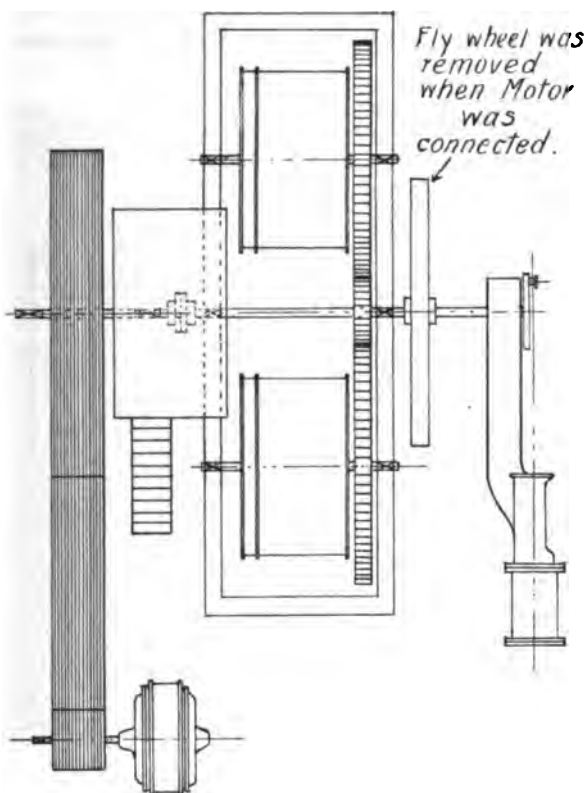


FIG. 6.—TANDEM DRUMS DRIVEN BY EITHER ENGINE OR MOTOR.

electrically driven plant. A new hoist has also been supplied for the circular concrete-lined shaft at Brier Hill. These last two hoists will be described more in detail.

The motors of the four principal hoists are all of standard design. They are three-phase, 60-cycle, 2,200-volt induction motors with wound rotors and external resistance for starting.

Experience shows that the motors at West Vulcan, Curry, and Brier Hill are much larger than is required. A motor of 200 h.p. would be sufficient for the requirements of any of the above shafts.

	Horse-power	Revolutions per Minute	Skip Load Pounds	Present Maximum Travel of Skip	Speed of Skip or Cage per Minute Feet
East Vulcan No. 4	200	360	6,700	1,557	590
West Vulcan	350	360	6,000	1,546	588
Curry	350	360	12,000	1,410	600
Brier Hill	450	300	12,000	989	600

The first hoist at these mines constructed solely for electric hoisting was installed at the Brier Hill shaft. This hoist has two drums with

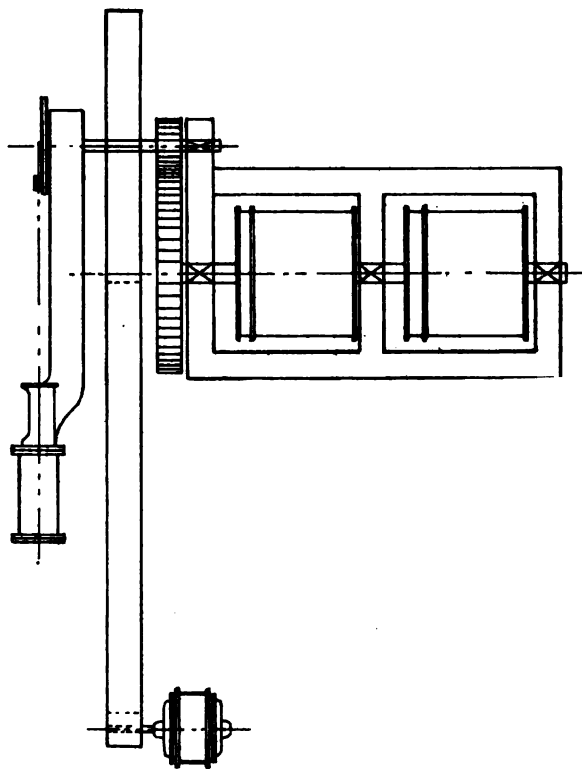


FIG. 7.—PARALLEL DRUMS DRIVEN BY EITHER ENGINE OR MOTOR.

shells of steel plate 12 ft. in diameter by 5 ft. 9 in. face, and 2 cast-iron conical drums, of which the small diameter is 4 ft. 6 in. and the large diameter 17 ft. These drums are keyed on two parallel shafts as shown in Fig. 8, a cylindrical and a conical drum on each shaft. Each drum is driven by a Lane friction clutch from a cut spur gear having 144 teeth, 4-in. circular pitch and 12-in. face. The pinion has 46 teeth, giving a gear ratio of 3.13 to 1. On the pinion shaft is a rope wheel 21 ft. 6 in. in diameter, having 24 grooves for $1\frac{1}{4}$ -in. manila rope. The pulley on the

motor is 48 in. in diameter. The friction clutches and band brakes are operated by compressed-air cylinders each having an oil cylinder to prevent jumping and to hold it at any point. Safety devices on this hoist fulfill the same conditions as those on the Curry hoist, but are more complicated and will not be described in detail here.

Before putting in this plant it was thought that a hand-operated controller for so large a motor as 450 h.p. would be hard to handle, so an automatic controller operated by alternating-current solenoids with a master controller was installed. This controller required frequent atten-

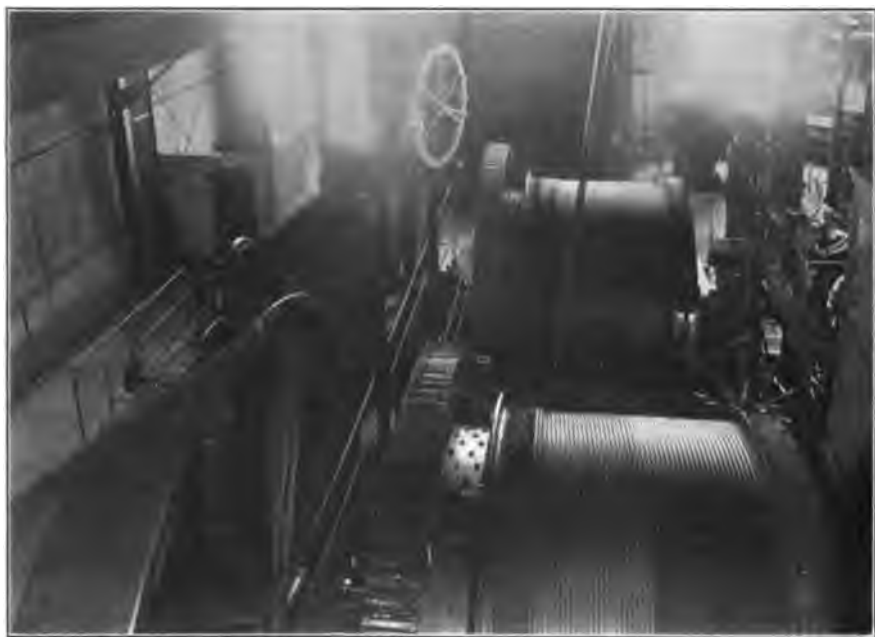


FIG. 8.—HOIST AT BRIER HILL SHAFT.

tion and was very noisy. It has been replaced with a water rheostat, which after some experimenting was built as shown in Fig. 9. The tank is of concrete, open on top and nearly full of a weak solution of carbonate of soda. A timber crosshead is suspended above the tank and to the under side of it four iron plates are attached. The plates are connected to the three secondary leads from the motor as indicated in the drawing. The crosshead and plates are raised and lowered by a rope which leads from an air cylinder in the hoist house. The plates are trapezoids in shape with the shortest side down and they are set at angles to each other so that the lowest parts are at the greatest distance apart. As the plates descend into the water the areas increase rapidly and the parts at the

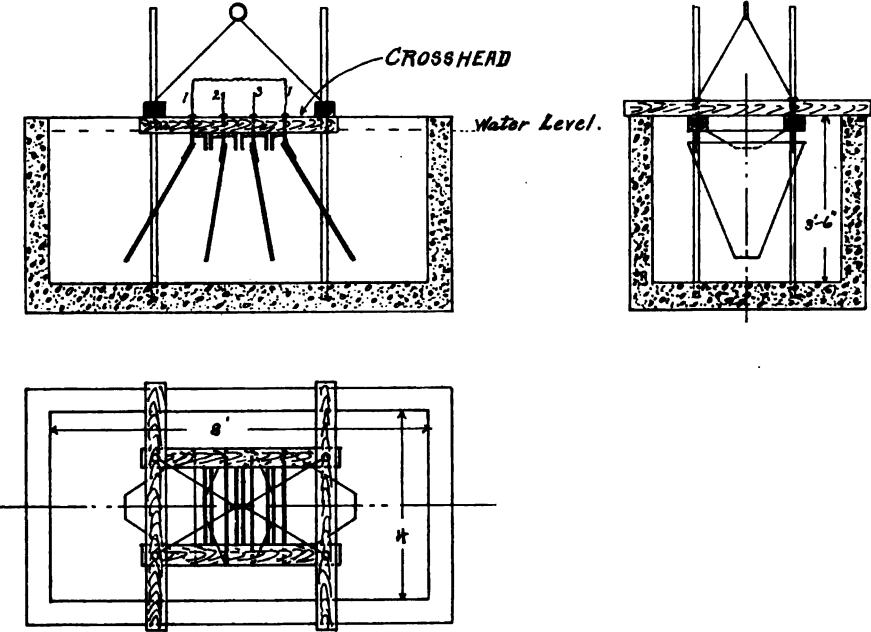


FIG. 9.—WATER RHEOSTAT CONTROLLER FOR 500-H.P. INDUCTION MOTOR HOIST SERVICE.

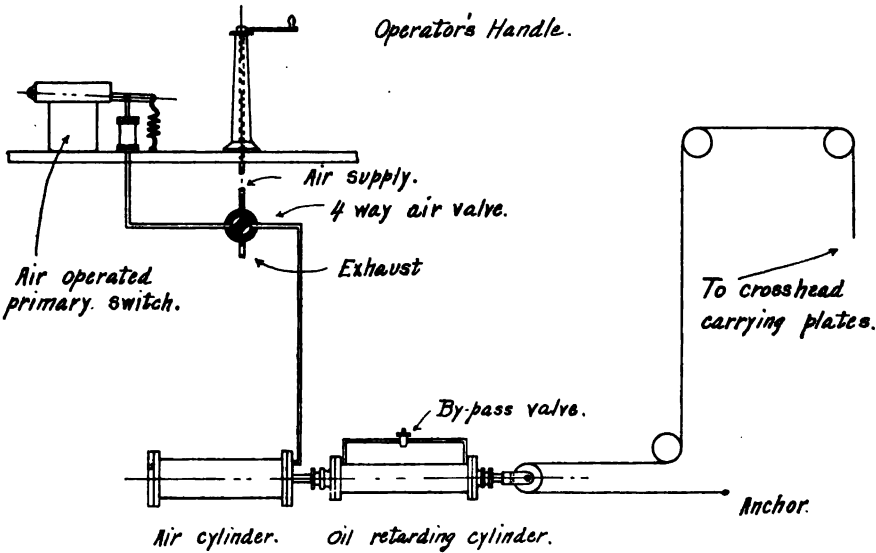


FIG. 10.—OPERATING MECHANISM FOR WATER RHEOSTAT.

surface of the water are closer together, so that the electrical resistance is reduced. The setting of the plane of the plates at an angle with the perpendicular also stirs up the solution to some extent. Between each pair of plates are smaller plates much closer together, electrically connected to the large plates, and at such a height that they enter the water just as

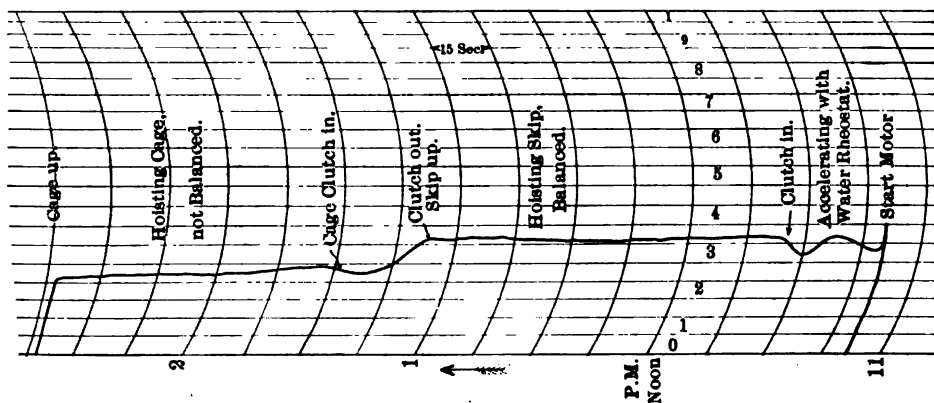


FIG. 11.—STARTING CURVE WITH WATER RHEOSTAT.

the large plates become completely submerged. By adjusting the distance between these small plates the amount of slip of the motor when pulling full load at full speed can be varied.

The mechanism for regulating the speed with which the plates are

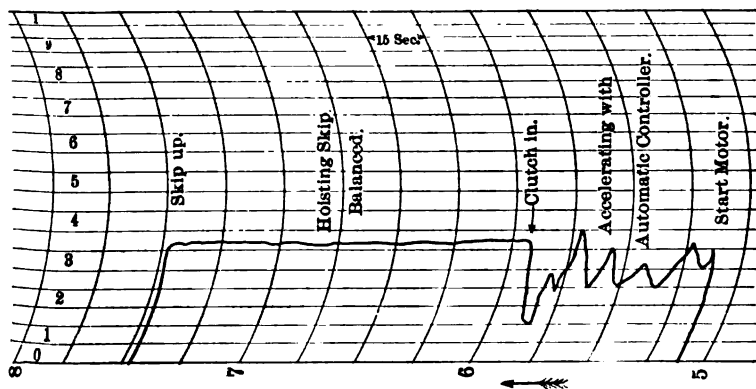


FIG. 12.—STARTING CURVE WITH AUTOMATIC CONTROLLER.

lowered into the water, for raising the plates out of the water, and for operating the primary switch is shown in Fig. 10. A four-way valve having only two positions, "on" and "off," is handled by the operator. In the "on" position air is admitted to a small cylinder which closes the primary switch, and the pipe leading to the air cylinder is opened to

exhaust. The weight of the crosshead and plates causes them to sink into the water at a speed determined by the amount of opening of the by-pass valve on the oil cylinder. When the hoist is nearly completed the operator throws the handle to the "off" position. This allows the air in the primary switch cylinder to exhaust, thereby opening the switch, and at the same time admits air into the air cylinder, thus raising the plates nearly out of the water.

Fig. 11 shows the starting curve with this water rheostat. Fig. 12 shows the corresponding curve with the automatic controller previously

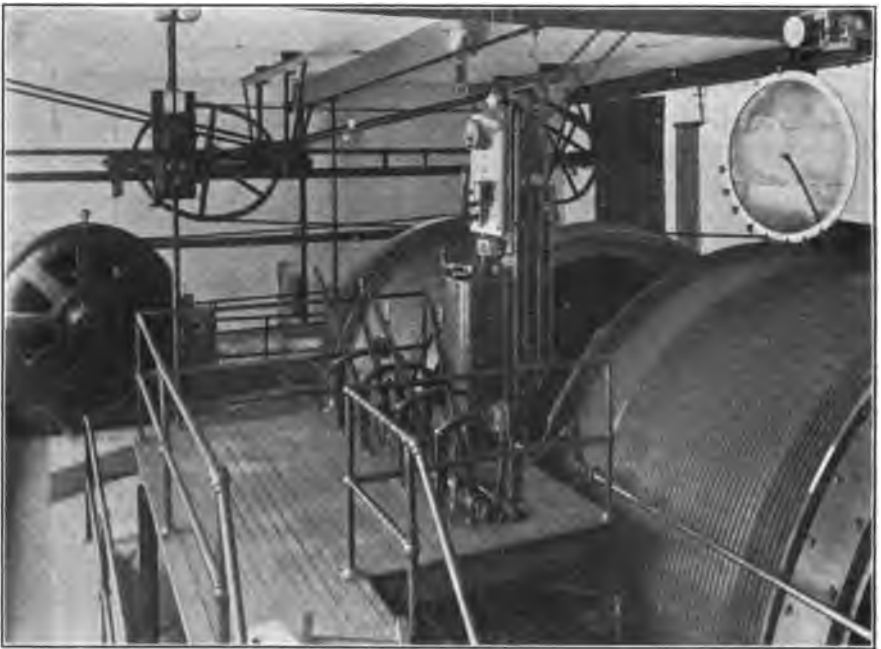


FIG. 13.—HOIST AT CURRY SHAFT.

used. On comparing these it will be seen that acceleration was accomplished with the water rheostat in 20 sec., while it took 40 sec. with the automatic controller, and the power drawn from the line was much more uniform with the former. The curve in Fig. 11 also shows the practically perfect counterbalancing of the skip and the unbalanced load of the cage.

The Curry hoist, shown in Fig. 13, was designed and built by the Penn Iron Mining Co. It has been in service since March, 1912. It has two cast-iron drums 12 ft. in diameter by 6 ft. face on the same shaft, each drum having a band brake 10 in. wide, 12 ft. in diameter, and driven.

independently by a Lane friction clutch 12 in. wide, which grips a friction ring 10 ft. 4 in. in diameter.

The main shaft is driven by a Falk cut helical gear having 181 teeth, $1\frac{1}{4}$ -in. circular pitch, and an 18-in. face. The pinion meshing with this gear has 19 teeth, giving a gear ratio of 9.52 to 1. On the pinion shaft is a rope wheel 9 ft. 10 in. in diameter having 24 V-grooves for $1\frac{1}{4}$ -in. manila rope. The rim of this rope wheel is $3\frac{1}{2}$ in. thick, to give it the proper amount of enertia. This rope wheel is driven from the 350-h.p. motor by a rope pulley 50 in. in diameter.

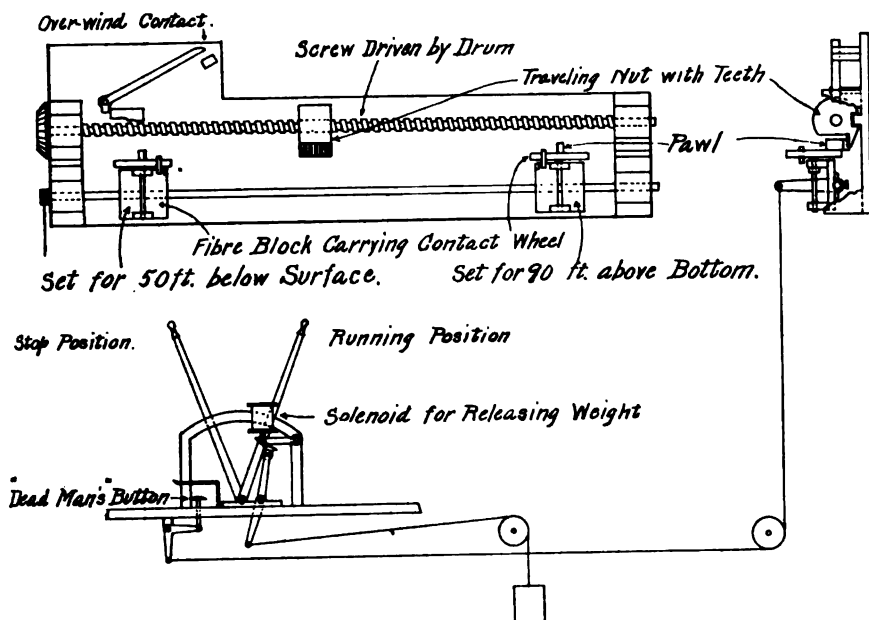


FIG. 14.—SAFETY DEVICE ON HOISTS.

The friction clutches and band brakes are power operated. In the basement is a small motor-driven triplex pump which takes oil from a suction tank and pumps it into a pressure tank. When all the oil in the system is in the pressure tank it is only one-third full of oil, two-thirds of the volume being compressed air at 80 lb. gauge pressure. As fast as oil is used and exhausted into the suction tank the pump puts it back into the pressure tank. When there is no oil in the suction tank the pump draws air, which is compressed and delivered into the pressure tank. A small safety valve allows the escape of any excess air. The brake is released by an oil cylinder and set by a weight, oil being admitted or exhausted by a three-way valve. The hand lever operating this valve is connected differentially to the brake lever so that the brake follows the operator's hand. The clutch is engaged by an oil cylinder and released

by a weight in the same manner. The use of oil under pressure instead of compressed air or steam insures smooth action of the clutch and brake, making sudden starting or stopping almost impossible, while the use of weights to release the clutch and set the brakes insures a reliable source of power for stopping.

The safety device stops the drum under any one of four conditions, viz.: Lowering too rapidly; overwinding; at a point 90 ft. above the bottom when lowering; and at a point 50 ft. below the surface when com-



FIG. 15.—FLY-BALL GOVERNOR FOR SPEED CONTROL.

ing up. The two latter stops are under the control of the brakeman, so that if he is aware of the position of the cage or skip he can disconnect either of these two devices. Referring to Fig. 14, the levers which operate the valves of the clutch and brake cylinders are shown, one in the "running" position and one in the "stop" position. A solenoid is arranged to release a weight which puts both clutch and brake levers into the "stop" position. It remains then to have a contact made that will send a current through the solenoid when it is desired to stop the drum. The contact for stopping when lowering too rapidly, the condition first mentioned, is made by a simple fly ball governor, shown

in Fig. 15. The other three conditions are controlled by means of the device shown in Fig. 14. A screw, driven by the drum, carries a nut with teeth which strike a pawl on the contact wheel, turning the wheel slightly and thus making a contact. By slightly turning the shaft which carries the contact wheels, the pawls are lifted and the nut travels under without turning the wheel. The shaft may be turned by pressing on the "dead man's button." The contact for the overwind needs no description. Fig. 15 gives a general view of this safety device. This device has been tried many times and all of the four conditions have always been met.

The ore formations at Vulcan are inclined at varying angles from 45° to 90° from the horizontal, but all the shafts are vertical with the

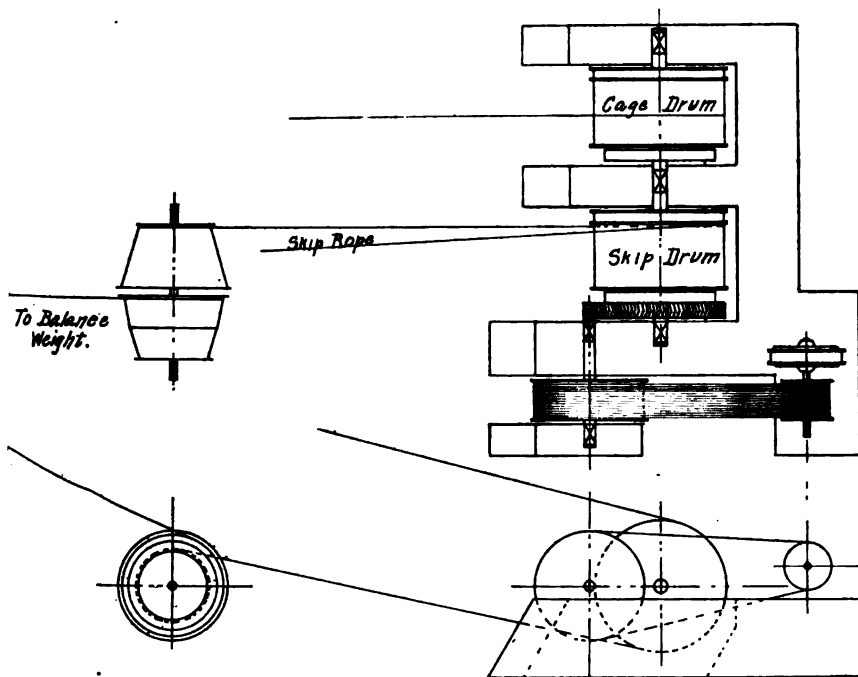


FIG. 16.—ARRANGEMENT OF CURRY HOIST AND BALANCE DRUMS.

exception of the lower part of East Vulcan No. 4. The ore bodies are very irregular in shape and may be considered ore shoots rather than lenses. The quantities on different levels vary greatly. For this reason hoisting with independent drums rather than with drums in balance presents advantages. A single drum at any of the shafts will carry all the ore required and work more or less intermittently. This economizes shaft space, and with a plant of two drums one can be used for a skip and the other for a cage.

In the important installations the weight of the skips, and when heavy the weight of the cage, is counterbalanced by a weight in the

shaft. The road for the counterbalance requires very little space in the shaft, as the counterbalance is made fairly long and small in the other directions. In one case an old Cornish pump plunger 16 in. in diameter and 10 ft. long partly filled with scrap has been used.

At East Vulcan No. 4 and Curry, in order to balance and equalize the weight of the ropes, the counterbalance rope, after leaving the hoisting drum, passes outside of the hoisting house to one of two connected conical drums toward its smaller diameter, while from the larger diameter of the other drum another rope leads to the shaft and carries the counterweight, as shown in Fig. 16. The uniformity of the balancing throughout the travel of the skip in the Curry hoist is shown in Fig. 17. In the Brier Hill plant, instead of the pair of conical drums outside the hoisting house there is a conical drum on the shaft with each of the

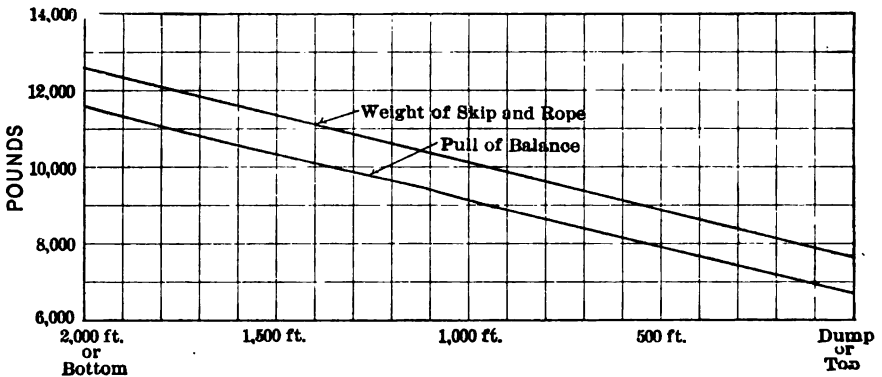


FIG. 17.—CURVES SHOWING VARIATION IN BALANCE WITH CURRY BALANCE DRUMS.
1½-in. hoisting rope, 4,900 lb.; skip weighs 7,600 lb.; weight of counterbalance, 8,260 lb.

main hoisting drums and the counterbalance rope leads from the smaller end of the conical drum (see Figs. 8 and 18). This arrangement is possible only when the hoisting drums are set tandem to each other. The strains on the counterbalance drum are so much less than on the hoisting drum that it can be very much lighter and there are fewer difficulties in its structural features than where conical drums are used for hoisting. The counterbalancing of the ropes by means of a single conical drum necessitates the use of a drum with a wide difference between its end diameters, a difference which in some cases is almost impracticable, and in any case requires deep grooving. Such a drum is more expensive both for itself and for the inclosing building than the pairs of drums used on the other plants and is heavier, thereby increasing the inertia.

In order to equalize the weight of the ropes in every part of the shaft as nearly as possible the angle of the cones must be carefully designed. To obtain absolute equalization would require a cone of which the

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Notes on an Iron-Ore Deposit Near Hong-Kong, China

BY C. M. WELD, NEW YORK, N. Y.

(New York Meeting, February, 1914)

THE southeastern coast of China, from Ning-Po to Macao, represents an element in the continental mass of Asia which has at practically all times in the remote past exhibited a tendency to rise rather than to subside.¹ This strip of land, 1,000 or more miles long by perhaps 150 miles wide at its widest part, has in fact stood above sea level since at least early Cambrian times, while the great basins to the north and west were receiving their massive accumulations of Sinian (Cambro-Ordovician), Carboniferous, and later deposits.

We find, therefore, a coastal fringe of metamorphic and igneous rocks bordering the huge expanses of sedimentary rocks which occupy the interior. Hong-Kong is situated toward the southwestern extremity of this fringe.

Hong-Kong is an island of approximately 30 sq. miles, on the north shore of which is situated the city of Victoria with its 325,000 inhabitants. This island was ceded to Great Britain in 1842. In 1860 the peninsula of Kowloon (about 5 sq. miles), being that part of the mainland lying directly across from the city of Victoria, was added to Hong-Kong. Thirty-eight years later, in 1898, a stretch of territory, including the mainland behind Kowloon and numerous adjacent islands, was leased to Great Britain for 99 years. This last addition is known as the "New Territory of Hong-Kong" and comprises 376 sq. miles in area.

A map of Hong-Kong, Kowloon, and the "New Territory" is shown in Fig. 1. My studies of this total area of over 400 sq. miles were devoted primarily to an investigation of the mineral resources. Systematic mapping of the immensely complex exposures of rocks was not possible in the time at my disposal. However, observations in this direction warrant a few generalizations.

The area in question is largely occupied by granite, for the most part rather coarsely crystalline, with quartz, potash-feldspar, hornblende, and subordinate quantities of mica as its chief constituents. Scattered throughout the granite are irregular masses of highly metamorphosed

¹ Bailey Willis: *Research in China*, vol. ii, chap. viii (Carnegie Institution, Washington, 1907).

sediments, in fragments ranging in size from a few cubic feet up to the immense quartzite peaks of Ma-On-Shan mountain. At and near contacts the granite exhibits fine-grained and porphyritic facies. In plan the area may be conceived of as a highly irregular mosaic, with baked sedimentary fragments of every size and shape set rather sparsely and absolutely at random in a matrix of granite.

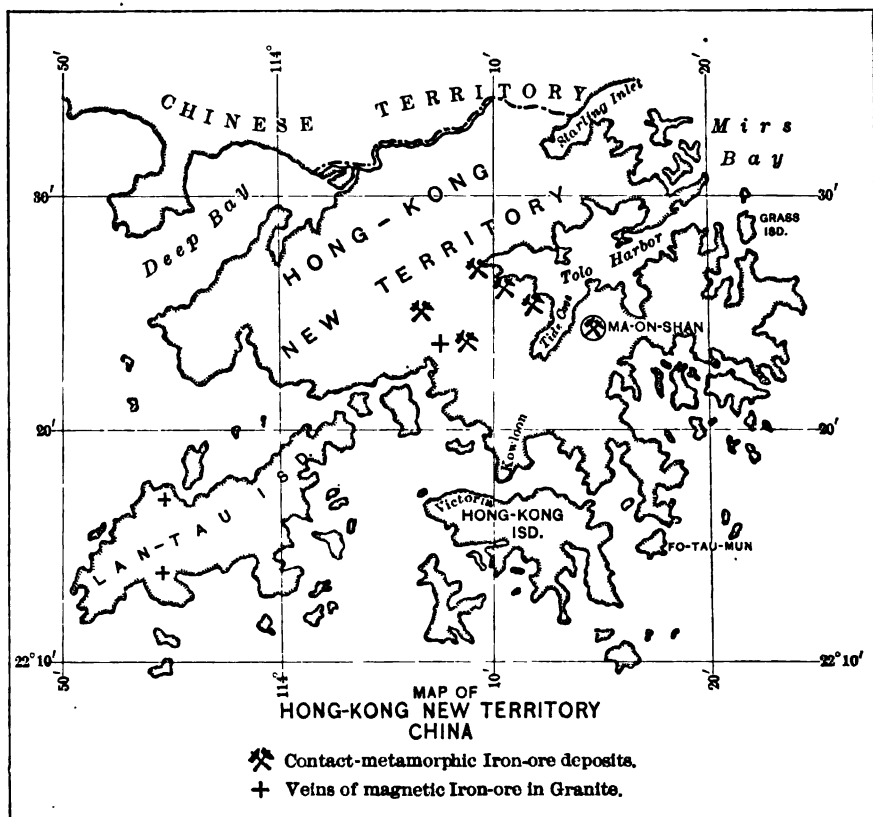


FIG. 1.—MAP OF HONG-KONG NEW TERRITORY, SHOWING IRON-ORE DEPOSITS.

Among the metamorphosed inclusions the most abundant are quartzites. Next come graphitic schists and clay slates. These are particularly abundant toward the northwest, finally coming in in great force and to the total exclusion of the granite along the northwest frontier, where they strike northeast to southwest and dip to the northwest. Occasional evidences of impure limy or magnesian carbonate rocks were also observed.

Along the eastern shore of the "New Territory," from Grass Island to Fo-Tau-Mun, large masses of basalt were seen, exhibiting marked

columnar structure. Von Richthofen² refers to the presence of "quartzose porphyry and its tufas" on the island of Hong-Kong; these were not observed by me.

We have then an area occupied chiefly by an intrusive granite, carrying immense numbers of baked sedimentary inclusions of every size and shape. Along the northwest border of this area the granite gives way to schists and slates, dipping to the northwest. Along the eastern and southeastern edge are masses of basalt and quartz-porphry.

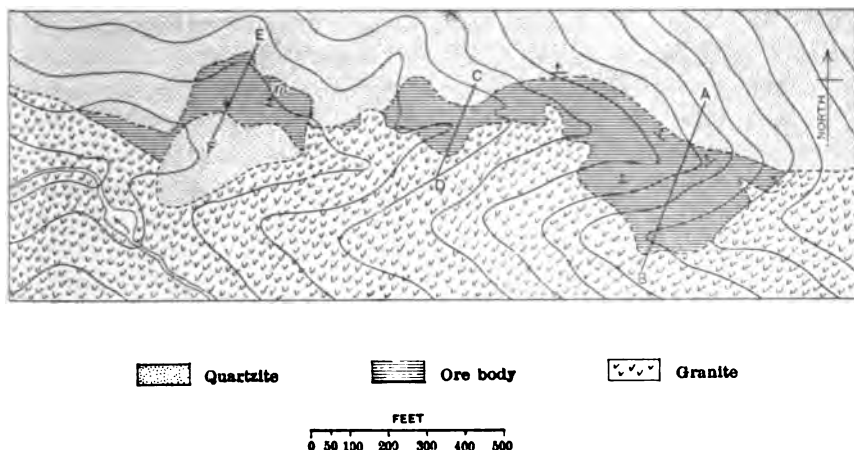


FIG. 2.—GEOLOGICAL MAP OF THE MA-ON-SHAN IRON-ORE BODY.
Contour Interval, 40 ft.

The geologic history of this area may be readily interpreted. Sediments, probably of pre-Cambrian age, including sandstones, shales, and a few impure limestones or dolomites, were invaded at depth and shot to pieces by immense masses of granite. The northwest border of the intrusion appears to have more or less coincided with the present northwest frontier of the "New Territory." (The frontier line was in fact established for strategic military purposes so as to include the coastal mountain ranges, and divides these from the lower-lying areas of the interior.)

Vertically upward movements followed upon the period of intrusion and have continued to persist since early Cambrian times, maintaining the "New Territory" continuously above sea level, and bringing about the ultimate exposure through denudation of what is probably not far from the summit of the granite batholith, with its included fragments. At some period later than that of the granitic intrusion, renewed volcanic activity gave rise to the basalts and porphyries.

²*Proceedings of the American Academy of Arts and Sciences*, vol. viii, p. 117 (1869).

Topographically the "New Territory" presents a land surface only moderately advanced in its erosional cycle. A few broad valleys have been carved out and all traces of a possible ancient peneplain have been removed. For the most part, however, the land is mountainous, with peaks rising as much as 3,000 ft. above sea level, frequently exhibiting steep slopes and torrential streams. Erosion processes have still much work to perform to balance the effects of the last period of elevation.

In the meanwhile we find evidences of a present reversal of the usual order of things. A glance at the map, Fig. 1, reveals numerous deep

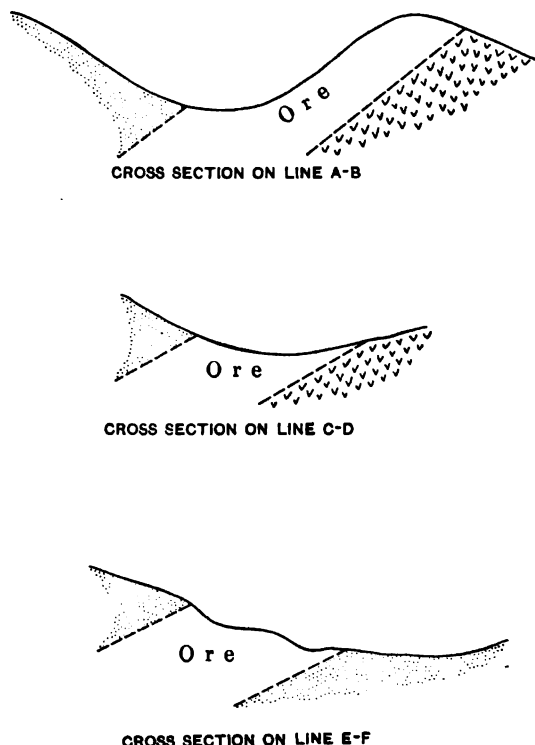


FIG. 3.—CROSS-SECTIONS, LOOKING EAST, ON THE LINES A-B, ETC., OF FIG. 2.

indentations and peaked islands, with deep-water harbors and channels close to shore. In short, the "New Territory" is clearly to-day a good example of "drowned" topography. Thus the latest chapter in our history points to a period of vertical subsidence, following upon the tendency to rise which has persisted through so many geological eras.

It is not surprising that an area with a history such as the above should show abundant and varied evidences of mineralization. Gold and silver, lead, zinc, copper, and tin have all been discovered at various localities. Iron-ore deposits have also been recorded, including secondary

surficial deposits, occasional small veins, and contact deposits. One at least of this last type possesses economic interest and it is my purpose to present a description of it.

The Ma-On-Shan iron-ore body lies somewhat less than a mile southwest of Ma-On-Shan peak. Its position is marked on Fig. 1. The distance in a direct line to Tide cove is about $1\frac{1}{2}$ miles, and not more than $2\frac{1}{2}$ miles to the navigable waters of Tolo harbor.

This ore body has been explored to some extent. It is first seen about $\frac{1}{2}$ mile southeast from the village of Ma-On-Shan and extends in an easterly direction up a small creek for a total distance of nearly 2,000 ft. Its western extremity lies 800 ft. above sea level and its eastern extremity 1,200 ft. Ma-On-Shan peak rises to an elevation of 2,260 ft.

Fig. 2 is a geological map of the ore deposit. Three types of rocks are distinguished, these being, in general, quartzite on the north, ore

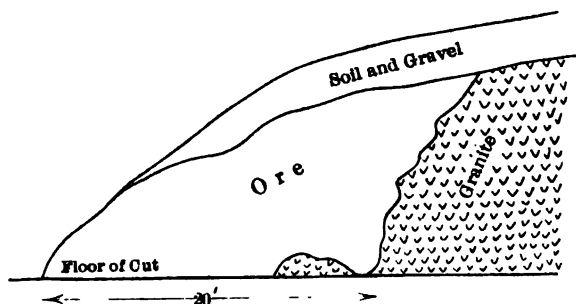


FIG. 4.—SKETCH OF EAST WALL OF SOUTHWARD-BEARING CUT, SHOWING CONTACT BETWEEN ORE AND GRANITE.

and its associate in the center, and granite on the south. The ore bed and quartzite dip toward the north at from 30° to 60° from the horizontal. At one point a considerable area of quartzite intervenes between the ore and the granite, and evidences of the same relations are found toward the east, where a southward-bearing tunnel started well within the ore area encountered a foot-wall of quartzite instead of granite. A drill hole also found quartzite underlying the ore. At most points where the contact is observable, however, the ore lies directly upon granite.

It is apparent that the sedimentary rocks, including sandstone and an intercalated bed of what is assumed to have been originally an impure dolomite (to-day represented by the ore and its associate—this point will be discussed more fully below), have been intruded by great masses of granite. The contact shown on the geological map (Fig. 2) is a small portion only of the southern edge of an immense fragment of quartzite, constituting Ma-On-Shan mountain, and entirely surrounded by granite.

This fragment possibly represents an uneroded portion of the original cover resting upon the summit of the granite batholith. At the point where the ore occurs the granite penetrated but did not entirely remove the dolomite bed. Thus a few shreds of dolomite were here left clinging to the edge of the sandstone, partly protected by remnants of the underlying sandstone. Both to the east and to the west the dolomite bed either did not originally exist or else was torn away and removed by the granite. At least, no trace of it appears to-day and the quartzite is seen in direct contact with the granite.

South of Starling inlet, $8\frac{1}{2}$ miles due north from Ma-On-Shan, a lenticular bed of magnesian or limy shale was discovered, of limited extent and grading on its strike into sandy shale. It is believed that this may be in some degree a counterpart of the original rock of the Ma-On-Shan ore body.

Three more or less idealized cross-sections of the Ma-On-Shan ore body are shown in Fig. 3. The sedimentary beds are seen dipping to the north. In one case quartzite is shown underlying as well as overlying the ore body. Just what the altitude of the granite contact may be is problematical. At the few exposures where it was possible to observe conditions the contact line was sharp but highly irregular, with a general dip toward the north. Fig. 4 is a sketch of the east wall of a small southward-bearing cut which crossed the contact.

That the sedimentary rocks have been dislocated is abundantly shown by the geological plan, Fig. 2. At least three considerable faults are seen, trending north-northeast to south-southwest, with the down-throw on the northwest side. The westernmost fault was clearly revealed by a tunnel which started in the overlying quartzite and bore eastward through the fault zone into the ore body. These faults do not cut the granite. They either antedated the intrusion or possibly were due, in part at least, to the shock of this event.

The granite is similar to that found throughout the Hong-Kong Territory. Its essential constituents are quartz and potash-feldspar, with subordinate quantities of hornblende and mica, chiefly muscovite. No microscopic examinations were made. At or near the contact it is fine-grained to (occasionally) porphyritic, in the latter case exhibiting at times conspicuous twinned orthoclase phenocrysts. Away from the contacts the texture is coarser. In color it is usually light gray, but more rarely pink, due to the presence of pink feldspar.

The quartzite lying north of the ore body is rather sandy in texture, generally altered and stained; no fresh exposures were observable adjacent to the ore body. The underlying quartzite is a dense, exceedingly hard white rock, with few or no minerals other than quartz visible to the naked eye. At one point scant veinlets of molybdenite were found.

The ore-bearing bed furnishes a most interesting study. I have referred to this as having probably originally been a bed of impure dolomite; a suggestion which carries with it a definite hypothesis regarding the genesis of the ore body, and which therefore requires development. As already stated, it dips toward the north at from 30° to 60° from the horizontal. It is about 100 ft. thick where its full thickness can be measured between quartzite walls, but not so thick where it lies upon granite.

It is not a solid mass of iron ore, but is broadly divisible into two members: namely, pure magnetite, and what was termed provisionally in the field "greenstone," but which closely resembles the "skarn" of the iron-ore belt of central Sweden. I shall therefore call it skarn in the following. This is a deep green rock, breaking into angular fragments where weathered, generally aphanitic, but from time to time presenting to the naked eye one or more of the following minerals: magnetite, quartz, garnet (frequently abundant), pyroxene, amphibole, mica, chlorite, epidote, serpentine.

The relations of the magnetite and the skarn are highly irregular. As a rule, it may be said that the magnetite occurs abundantly disseminated throughout the skarn, in bodies ranging from isolated minute crystals up to pure masses comprising thousands of tons. In its pure, massive form the magnetite is generally rather soft and granular. There are no well-defined boundaries between the magnetite masses and the skarn, the one grading imperceptibly into the other. The skarn frequently carries sufficiently high proportions of magnetite to constitute a commercial iron ore in itself.

In the following table I present five analyses of Ma-On-Shan ores and skarn. Nos. I and II were taken from the richer portions of the ore body, while No. III represents magnetic concentrates. In this case 22 samples of lean ores and skarn, taken from all portions of the deposit, were treated in the laboratory with a horseshoe magnet and the concentrates thus obtained were sent up for analysis. No. IV was an average sample of ore, and No. V was lean ore or rich skarn. Analyses I and V were made at the laboratory of the Langloan Iron & Chemical Co., Coatbridge, England; analysis II at the Gwendoline mine, Korea; analysis III by Riley & Co., Bombay, India; and analysis IV by Pearson Claudet, London, England.

On viewing these analyses we note that not all the iron occurs as magnetite, there being a considerable proportion of hematite, particularly in analysis III.

A most striking feature of the analysis is the great amount of magnesia, especially as compared with the almost insignificant amount of lime. The five results given in the table do not, however, represent the invariable ratio of these two elements. Thus eight other samples, all

of skarn, analyzed in a private laboratory in Hong-Kong, yielded an average of 6.05 per cent. CaO and 5.58 per cent. MgO, with considerable amounts of "insoluble matter."

	I	II	III	IV	V
Fe ₂ O ₃	70.32	65.25	75.36	62.24	38.40
FeO.....	22.53	22.26	11.37	15.75	15.84
MnO.....	1.48	.....	0.70	1.03	0.74
SiO ₂ }	1.20	{ 3.99	5.50	6.04	12.70
Al ₂ O ₃} } .....	.....		4.46	1.80	1.21
CaO.....	0.60	.....	0.73	0.56	0.40
MgO.....	3.64	Trace	2.29	11.53	26.24
S.....	0.110	0.27	0.082	0.09	0.192
P ₂ O ₅	0.009	0.044	Trace	.....	0.028
As.....	0.008	.....	Nil	.....	0.005
CO ₂.....	.....	.....	Nil	0.80	1.50
Water.....	.....	7.20	Trace	.....	.....
Moisture.....	.....	.....	.....	.....	0.10
Loss.....	.....	.....	.....	0.16	.....
Total.....	99.897	99.014	100.492	100.00	97.355
Fe.....	66.75	63.00	61.59	55.82	39.20
P.....	0.004	0.019	Trace	.....	0.012

Four specimens were submitted to microscopic examination, as follows: (a) and (b), typical skarn with angular jointing; (c), skarn with iron ores and garnet; (d), skarn, iron ores more prominent and showing quartz, feldspar, and ferro-magnesian minerals. The following description of the micro-slides were returned, giving the minerals observed in the order of their quantitative importance.

(a)		(b)	
	First Slide		Second Slide
1. Uralite.	1. Uralite.	1. Uralite.	
2. Colorless pyroxene?	2. Colorless pyroxene?	2. Magnetite.	
3. Magnetite.	3. Magnetite.	3. Periclase?	
4. Periclase?	4. Periclase?	4. Pyroxene?	
(c)		(d)	
	First Slide		Second Slide
1. Colorless twinned pyroxene.	1. Pyroxene.	1. Pyroxene?	
2. Magnetite.	2. Magnetite.	2. Magnetite.	
3. Secondary aggregate formed from 1.	3. Secondary serpentine.		

The mineral determined as periclase (described as a colorless isotropic mineral with a high refractive index) was so designated only with hesitation. However, the excess amount of magnesia shown by the analyses lends generous support to this determination, leading to the supposition that when the rock was developed into its present state a part of the magnesia combined with the silica, lime, and alumina to form pyroxene, while the excess remained as free magnesia or periclase.

Taking the results of the micro-slides broadly, in conjunction with the analyses, it would appear that the typical unaltered aphanitic portions of the skarn consist essentially of lime-magnesia-pyroxene, magnetite, and periclasite. The more coarsely crystalline portions reveal, in addition to magnetite and not readily distinguished ferro-magnesian minerals, quartz, frequently abundant garnet, mica, chlorite, epidote, and serpentine.

Without the field evidence the magnetite-skarn body might be adjudged a magmatic differentiation out of an ultra-basic rock. As it is, it is believed to be of contact-metamorphic origin. It seems probable that this ore-bearing bed, lying partly intercalated with quartzites and in contact with an intrusive batholith of granite, has been developed out of an originally non-ferruginous but easily vulnerable rock through the selective impregnation of mineral-bearing emanations from the granite magma.

Examples of contact metamorphism where limestone beds have been locally wholly replaced by iron ores, associated with a variety of minerals generally similar to those found in the Ma-On-Shan ore body, are well authenticated and numerous. Perhaps the only striking difference between these authenticated occurrences and Ma-On-Shan is the extraordinary abundance of magnesia in the latter. This we may account for by the obvious suggestion that the original rock was one rich in magnesia—namely, a dolomite.

The high-magnesia characteristic is not entirely unique, as may be seen by comparison with the published analyses of iron ores from the Tilly Foster and Mahopac mines of Putnam county, N. Y.;³ in that case, however, the magnesia is identified as present in the mineral chondrodite. Koeberlin⁴ attributes a contact-metamorphic origin to these ore bodies. Sjögren⁵ describes a similar occurrence and association at Nordmarken, Sweden.

The fact that the Ma-On-Shan deposit, as far as observable, is in the form of a bed does not preclude a contact-metamorphic origin for its ores. It would be but natural that where an intrusive has cut a series of beds of varying composition and texture, a selective attack, according to the vulnerability of the different materials presented to its field of action, has taken place.⁶ In this case the sandstone has suffered little

³ A. F. Wendt: *Trans.*, xiii, 481 (1884-85).

⁴ *Economic Geology*, vol. iv, No. 8, p. 749 (Dec., 1909).

⁵ *Trans.*, xxxviii, 796 (1907).

⁶ I may cite as a striking example of such a selective attack the magnetite ore beds near Dillsburg, Pa., described by Spencer (*Bulletin No. 359, U. S. Geological Survey*, pp. 74 to 96 [1908]) and Harder (*Economic Geology*, vol. v, No. 7, p. 599 [Oct.-Nov., 1910]). The Mahopac ore beds above referred to are also an excellent example.

beyond an intense baking, possibly also silicification. The dolomite bed, on the other hand, has been thoroughly saturated by the magmatic emanations. Carbonic acid has been practically wholly expelled (see analyses IV and V), as also probably a portion of the lime. Magnesia appears to have been more resistant and has largely remained; in part as periclase, in part combined with other elements to form new minerals. Large amounts of iron have been added and possibly small amounts of silica. In short, the dolomite bed has been converted in the vicinity of its contact with the granite into a magnetite-skarn bed, the latter following the lines and structural position of the former. If the ore bed could be followed to a sufficient distance away from the granite contact, it would probably be found in its original condition of impure dolomite.

The fact that the possibly pre-granitic faults cut the ore body does not indicate that the ore body likewise was pre-granitic. The dolomite bed suffered this faulting, and when replaced by ores and contact minerals these latter naturally followed out all of its structures, completely filling the spaces formerly occupied by it between the inclosing walls of impregnable sandstone.

I have indicated on Fig. 1 five other localities where iron-ore bodies similar to Ma-On-Shan but of smaller dimensions have been found. I have also shown three points where veins of magnetic iron lying wholly within granite areas have been discovered. These latter undoubtedly owe their metal to the same sources as the contact-metamorphic deposits, the veins being shrinkage fissures due to the cooling of the granite and filled by mineral-bearing solutions rising out of the still viscid interior. The presence of these fissure veins of magnetic iron further supports the hypothesis that the iron ores of Ma-On-Shan were derived from the granite and were not indigenous to the intruded sediments.

I conclude with the belief that there is sufficient evidence for assigning this interesting Chinese iron-ore deposit to the now well established contact-metamorphic or, as more narrowly defined by Leith,⁷ "pegmatite" class of ore deposits.

⁷ *Economic Geology*, vol. iii, No. 4, p. 277 (June-July, 1908).

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Nickel Deposits in the Urals

BY H. W. TURNER, SAN FRANCISCO, CAL.

(New York Meeting, February, 1914)

THE axis of the middle portion of the Ural mountains is made up chiefly of highly compressed igneous and sedimentary schists, considered of Devonian age by the Russian geologists, with large areas of serpentine (peridotite originally) gabbro, etc., intrusive in the schist series. In addition there are large areas of probably older granitic and gneissic rocks. The nickel deposits referred to in this paper are found in the Devonian schists and their associated igneous rocks. The gabbro-peridotite intrusions probably took place in late Devonian or early Permian time, inasmuch as the Permian and Carboniferous beds lie at gentle angles on the Devonian series on the west slope of the Urals.

Perhaps the first attempt to work a nickel deposit in the Urals was made about 1866 in the Revdinsk district, which is situated southwest of Ekaterinburg. I was informed by a Russian that a wet method of extracting the nickel was tried but was not a commercial success. This deposit has been described by Müller,¹ Foullon,² and Karpinski.³ Beck⁴ gives an abstract of these papers.

Lying to the southeast of the Revdinsk district, the Sissert estate intervening, is the Verkhne-Ufalei district, which is traversed by the railroad from Ekaterinburg to Cheliabinsk, as shown on the map, Fig. 1, there being a station on this railroad at the iron-smelting town of Verkhne-Ufalei. About 7 versts (4.6 miles) north of this town is the Nijni-Karkadinsk iron mine, which is a limonite deposit. In one of the shafts in this mine a serpentine rock showing a green mineral was encountered. A sample of this mineral collected in 1910 was tested by Mr. Wyatt, chief chemist of the Karabash laboratory of the Kyshtim Mining Works, and determined as nickel ore. A thin section of one piece of the serpen-

¹ H. Müller: Über die Nickelerzlagertstätten von Rewdinsk, *Berg- und Hüttenmännische Zeitung*, vol. xxv, No. 8, p. 65 (Feb. 19, 1866).

² H. B. von Foullon: *Jahrbuch der kaiserlich-königliche geologische Reichsanstalt*, vol. xliii, pt. 2, p. 234 (1892).

³ A. Karpinski: Über die Lagerstätten der Nickelerze im Ural, *Corni Journal* (Russian), St. Petersburg, 1891, No. 10.

⁴ *Lehre von den Erzlagertstätten*, 3d ed., vol. i, p. 518 (1909).

tine rock showed under the microscope serpentine apparently derived from olivine and the remains of orthorhombic pyroxene.

The occurrences are apparently similar in a general way to the New Caledonia deposits and those of small economic importance at Riddles, Ore., the silicate of nickel being secondary and the original nickel sulphide(?) being probably an original constituent of the peridotite from which the serpentine was derived.

In 1906-07 some prospecting for nickel was done at the Nijni-Karkadinsk mine by the foreign geologist Gannenbein, and continued in 1908 by the Russian geologist, Professor Krotoff. Some bore holes put down penetrated clay beds containing green nickel ore. The average

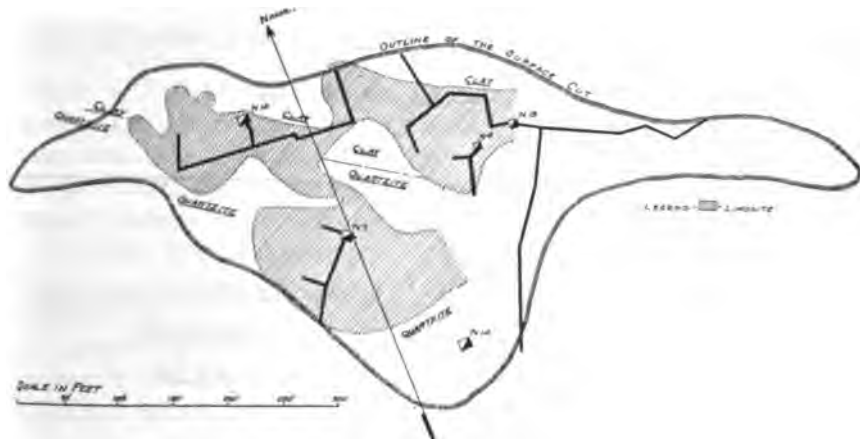


FIG. 2.—PLAN OF THE NIJNI-KARKADINSK MINE ON APPROXIMATELY THE 90-FT. LEVEL.

content of nickel in the samples from four bore holes was from 0.72 per cent. in bore No. 1 to 3.24 per cent. in bore No. 4.

What is probably a continuation of the Nijni-Karkadinsk nickel silicate deposit was found about 1,300 ft. to the northwest. Here Professor Krotoff sunk about 100 pits and uncovered a considerable quantity of clay containing the green nickel ore. The horizontal extent of these workings was an area about 250 ft. long in a northwest-southeast direction and 70 ft. wide. The general average of 35 samples, as determined by the chemist of the Ufalei Iron Works, was 2.82 per cent. Ni. A sample of nearly pure ore gave the following results: Ignition, 8.40; SiO_2 , 38.95; Al_2O_3 , 3.45; FeO , 1.56; CaO , 0.10; MgO , 1.00; NiO , 47.00 (= 37% Ni); total, 100.46 per cent.

The mineral is thus a silicate of nickel. All of this nickel silicate ore is presumably derived from the weathering of the adjoining serpentine, the nickel undergoing concentration.

In the Khudyakovsk iron mine, on the Ufalei estate, there is also nickel in the ore, assays by Johnson & Sons, of London, showing a con-

tent of from 0.08 to 0.11 per cent. of Ni in four samples and of from 0.02 to 0.04 of Cu. Here again there is a large serpentine area immediately adjoining the deposit on the east.

The Staro-Cheremshansk limonite mine, lying northwest of the Nijni-Karkadinsk, is very similar to the latter mine, the same granular quartz rock described later being present. This limonite ore also contains, in the sample assayed by Johnson & Sons, 0.95 per cent. Ni. There is serpentine to the west of the deposit, but the inclosing rocks so far as seen are the quartzite and talc-schists.

Another similar occurrence, but probably of no economic value, is at the Agardyash iron mine, on the Kyshtim estate. There is some serpentine along this deposit and green nickel ore was found carrying up to 5 per cent. Ni, according to the records of the Kyshtim laboratory.

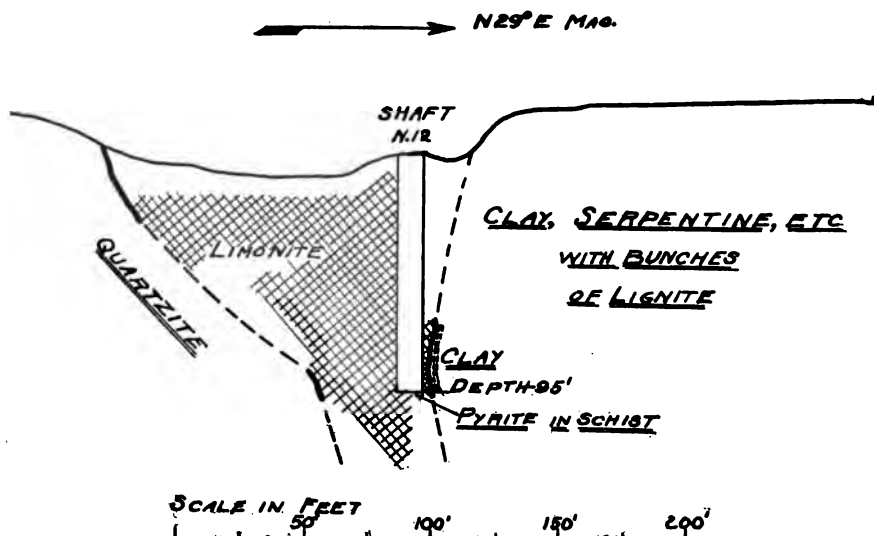


FIG. 3.—VERTICAL SECTION OF THE NIJNI-KARKADINSK MINE.

Going further afield, the Moa Bay limonite deposits⁵ of Cuba are in serpentine, the ore being a surface concentration from the decomposition of that rock. An analysis of the Moa Bay iron ore shows a content of nickel of 0.60 per cent. and of chromic oxide of 2.65 per cent. Nickel is also present in the limonite ores of Virginia where basic intrusives are absent. Thus the Oriskany (Devonian) ores contain from 0.05 to 0.1 per cent. NiO+CoO, and Potsdam (Upper Cambrian) limonite from the Blue ridge was found to contain 0.5 per cent. NiO+CoO.⁶

When prospecting for copper on the Ufalei estate in the fall of 1910,

⁵ C. M. Weld: *Trans.*, xl, 299 to 312 (1909).

⁶ *Trans.*, xxxix, 547 and 921 (1908).

I found at the bottom of shaft No. 12 in the Nijni-Karkadinsk mine some blue dirt containing a sulphide, apparently pyrite. The same mineral crystallized in cubical form was also found in some black dirt from another shaft. At the time this pyritic mineral was tested for copper, of which it contains traces, but it was not determined until some time afterward that it contained nickel. Later investigations showed that the pyrite was sprinkled through some of the iron ore in the bottom workings and in drill holes put down from these workings; and that carbonate of iron, or siderite, was present, and that the limonite was formed from the oxidation of the siderite.

The Tunkinsk iron mine, in the Serguinsk district, farther to the northwest, is of this nature, the bottom of workings at a depth of 150 ft. from the surface being carbonate of iron, while above that level nearly all the ore is oxidized into limonite. Here also the siderite contains a little iron sulphide showing on careful tests traces of copper. The Tunkinsk siderite ore bed is probably of sedimentary origin, and this is probably true of many of the iron mines in the extreme western part of the Kyshtim estate and of the Serguinsk district, and very likely is true of the ore bed of the Nijni-Karkadinsk iron mine.

The black dirt containing pyrite was found to be largely carbon, and this doubtless represents a bed of coal or lignite much broken up by later serpentine intrusions. A sample of the black carbonaceous material was analyzed by Johnson & Sons, of London, with the following result, the sample not being dried: Moisture, etc., 100° C., 35.65; volatile, 26.55; fixed carbon, 14.85; Ni and Co, 1.69 per cent.

Another portion of the same sample was burned, the ash and mineral matter forming 22.9 per cent. of the sample. The ash contained: Ni, 7.20; Co, 0.21 per cent.; fine gold, 0.01 oz.; fine silver, 0.50 oz. per ton of 2,240 lb.

It is thus evident that this carbonaceous ore can be concentrated by simple ignition into a commercial product, the question being largely one of quantity, which has not yet been determined.

To test the limonite-siderite deposit for nickel, 20 vertical bores were put down. The average of all the samples representing about 40,000 tons of iron ore is reported by Mr. Kerzin, the Russian geologist of the estate, to be 0.75 per cent. Ni. It is obvious that the nickel-bearing pyrite must be concentrated from the limonite-siderite gangue to be of commercial value; otherwise the only use of the nickel would be to improve the quality of the iron smelted.

The ore was subjected to an ordinary laboratory water-concentration test by Johnson & Sons, with negative results, as would be expected. A test was also made by T. J. Hoover by oil flotation, with negative results, due no doubt to the limonite present. However, as in depth the gangue may be entirely siderite, the oil-flotation method may still suc-

ceed, or some other method of concentration may be successful. Mr. Hoevelaken and colleagues in charge of the estate intended to have other tests made, but I have not been informed of the results.

A sample of the pyrite concentrated by hand panning—although not pure—contained, as reported by Johnson & Sons, 6.28 per cent. Ni. A sample of the same concentrate was examined by Prof. A. F. Rogers, of Stanford University, who reported that the “nickel-bearing sulphide has the crystal form of pyrite and lacks the octahedral cleavage of pentlandite.” He also determined that siderite was present as an impurity in the concentrate. Dr. W. F. Hillebrand, who made a provisional examination of the concentrate, considers it nickeliferous pyrite.

Origin of the Nickel-Pyrite Ore

The rocks of the Nijni-Karkadinsk mine comprise talcose schists in subordinate amount, but chiefly the rock called quartzite and serpentine. The so-called quartzite may in reality represent an original sandstone much changed by the addition of secondary silica. Some of it is porous, containing many little well-formed quartz crystals and sometimes pyrite, and looks not unlike the quartz of some granular quartz veins. Whether of sedimentary or vein origin, there is no question as to the deposition of much secondary silica, presumably from deep mineral-bearing waters. The carbonaceous material (lignite?) that occurs in irregular bunches along the east side of the mine may easily have been at one time a definite layer interbedded in the original sediments and broken up into patches by the peridotite (serpentine) intrusions. It seems very possible, therefore, that the serpentine is the mother rock of the nickel-pyrite, which was brought from the serpentine in magmatic or other solutions which soaked into the adjoining siderite deposit and into the lignite bed and deposited there their mineral contents. The same solutions very likely account for the quartzite as we now see it.

A plan, Fig. 2, and a vertical section, Fig. 3, of the Nijni-Karkadinsk mine are given herewith. While the rock immediately west of the limonite deposit is quartzite, a little farther west is a large serpentine area which extends for miles north and south. There is thus serpentine both east and west of the mine.

Kemp⁷ states that the ores of Mine La Motte and Bonne Terre in Missouri, are nickeliferous pyrite and (at the former in a subordinate way) siegenite, a sulphide of nickel and cobalt with a little iron. The pyrite is disseminated with galena in Cambrian limestone, while the siegenite is in an underlying sandstone. Small amounts of copper also appear in the mattes.

⁷ *Trans.*, xxiv, 620 (1894).

Dana states that nickeliferous pyrite has been observed at Sudbury, Canada.

Hillebrand⁸ has described a nickeliferous pyrite from an asphaltite-vanadium deposit at Minasragra, Peru, having a composition as follows: Sulphur, 45.06; iron, 25.38; nickel, 15.70; cobalt, trace; vanadium, 4.31; molybdenum, 0.09; carbon, 0.47; water (H_2O), 1.38 (partly from H of carbonaceous matter); titanitic acid (TiO_2), 0.93; silica (SiO_2), 1.93; alumina (Al_2O_3), with a little P_2O_5 , 2.45 per cent.

Hillebrand remarks: "If the vanadium is disregarded, the iron-nickel sulphide has the formula $(FeNi)S_2$, with iron to nickel as 1.70 to 1, or nearly 5 to 3. A pyrite with such a high proportion of nickel is unknown. But a single one of the analyses quoted in Hintze's Handbook of Mineralogy shows anywhere near 6 per cent. nickel; this one, however, showing also about 3 per cent. of cobalt. The nearest approach to the present case is seen in the mineral gunnarite, $3FeS_2$, $2NiS$, incompletely described by Lanstrom with density 4.3 and a tin-white color with a tinge of yellow, tarnishing yellowish-brown. The present mineral would seem to be quite distinct from gunnarite, and for the present is to be regarded as a highly nickeliferous pyrite. Should it seem proper to give it a specific name later, *bravoite* is suggested, after Señor José J. Bravo, the Peruvian writer on the vanadium occurrence at Minasragra."

⁸Hillebrand, W. F.: The Vanadium Sulphide, Patronite, and Its Mineral Associates from Minasragra, Peru, *Journal of the American Chemical Society*, vol. xxix, No. 7, p. 1019 (July, 1907).

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the New York meeting, February, 1914, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 30 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Apr. 1, 1914. Any discussion offered thereafter should preferably be in the form of a new paper.

The Burning of Coal Beds in Place

BY ALEXANDER BOWIE, BOWIE, COLO.

(New York Meeting, February, 1914)

In many places throughout the Western mountain plateau regions of the United States coal beds in place have been burned over very extensive areas, the fire evidently originating on the nakedly exposed outcrop of the coal bed and gradually burning its way into the bed for considerable distances under very heavy cover. The surface evidences of the burned-out coal beds are seen in the calcined and discolored rocks overlying the places of the outcrop. The greater the mass of the burned coal the higher the results of its combustion can be seen in the overlying strata. I have noted many instances of this condition in the States of South Dakota, Wyoming, Colorado, New Mexico, and Arizona. In the lignite fields of Dakota and Wyoming I noted stretches of level country many square miles in extent where the surface rocks were roasted and vitrified by the burning of a great bed of lignite lying nearly level and with a light cover; this is probably the most favorable natural condition for the burning out of a coal bed. The less the depth of the rock covering overlying the coal bed, the better the chance for a continuous supply of air to the fire; but when the coal bed dips heavily into the ground, or even if level, if it passes under a hill or mountain which gives the bed a heavy covering of strata, the fire has more chances of being extinguished from natural causes than in the first condition described.

The distance which a crop fire may extend into a coal field is very much influenced by the dip, the thickness of the coal bed, and the nature of the rock covering immediately overlying it.

In reasoning on this subject, it would seem logical to assume in the case of a coal-bed cropping at the base of a hill and dipping into it, with an extensive drainage surface above the crop line, that a crop fire would be promptly extinguished by the caving in of the overlying strata and the precipitation of the rainfall from the drainage surface above the outcrop through the breaks formed in the caving strata. This consideration would be more or less effective according to the climate of the location. In a humid climate where the rainfall was heavy the water from the natural precipitation alone would probably extinguish a crop fire before it could work its way very far under cover, but in an arid climate this preventive does not seem to be effective. I find that even under the

conditions I have suggested as being most unfavorable for the continuity of crop fires there are places where fires have persisted for long periods of time until the fire has eaten its way under a heavy cover for distances of from a few hundred feet to a half mile or more from the outcrop before they were finally extinguished.

In my mining experience two such cases have come under my observation, one in the development of the Caledonian mine, near Gallup, N. M., at an elevation of 6,500 ft. above sea level, and the other in the development of the mines of the Juanita Coal & Coke Co., in Delta county, Colo. In both cases the coal bed dipped away from the outcrop and in both cases the land rose for a considerable distance above the coal crop, forming a large drainage area, the run-off from which had to cross the line of outcrop.

In the Caledonian coal bed the coal was a high-class lignite about 6 ft. thick at the outcrop, with a stratum of hard sandstone about 25 ft. thick for a roof. As the mine was driven into the field a seam of soft clay shale, which gradually increased to a thickness of from $3\frac{1}{2}$ to 4 ft., came in between the top of the coal bed and the sandstone roof. The coal was found burned out at one point to a distance of nearly 500 ft. from the outcrop. In developing the mine we cut through into places where the sandstone roof stood up in its natural position unbroken and the upper half of the coal bed was burned off. All that was left of it was a few inches of fine white ashes covering the lower half of the coal bed, which was not consumed, but metamorphosed so that its cohesive property was destroyed and it was nothing but fine slack that would not ignite when placed on an ordinary fire. In this case the influence of the fire did not extend far beyond the place of the burning, as a few yards beyond the burned-out area we got coal of a quality good enough to ship. There was no evidence that water had played any part in extinguishing the fire, as the fine ashes overlying the under part of the coal bed were undisturbed; it had evidently expired for want of air by the packing of the earth between the fire and the outcrop. It occurred to me at the time that if the 4 ft. of soft clay shale had formed the roof of the coal bed at the outcrop the fire would have been smothered by the shale before it could have burned its way many feet from the outcrop.

I had an opportunity for further observation at the mine of the Juanita Coal & Coke Co., which is located on the north side of the North Fork branch of the Gunnison river, at an elevation of about 6,600 ft. above sea level. The mine is named the King mine and we refer to the bed in which it is opened as the King coal bed. At the point where the mine is located the stream flows nearly west and the high banks run approximately parallel to it and rise high above it on both sides. On the north side the surface rises abruptly to an elevation of from 1,200 to 1,500 ft. above the level of the stream and continues to rise for many

miles northward. The King mine is opened on the north side about 700 ft. above the level of the stream and 80 ft. above a great cliff-making sandstone ranging from 100 to 150 ft. thick, which forms the base of the coal formation and is commonly referred to as the basal sandstone. The mine enters on the outcrop of the coal bed, which comes to the surface at that point, although the coal is burned out along the outcrop on both sides of the opening. There is only a sparse covering of soil in patches along this hillside, the rocks for the most part being nakedly exposed, and one can trace the horizon of the coal bed in which the mine is opened for long distances and find nothing but calcined rocks. The dip of the coal bed is northeast and the main line of the development of the mine is northward; the rate of dip on the line of the main entries is about 5 per cent.

The coal mined next the outcrop was very soft and continued to be of inferior quality for about 700 ft. or more in from the outcrop.

The coal adjacent to the burned-out area seemed to have its cohesive quality entirely destroyed. It was soft and very easily mined, but could not be utilized even for steam fuel, as the volatile constituents of the coal seemed to have been expelled by the heat. We had a zone of several hundred feet of this kind of coal, which gradually became less fragile until we had coal that could be utilized for steam fuel; but passing it over a screen would yield a very small quantity of lump coal, a large percentage of nut and a still larger percentage of slack, while great clouds of fine dust would rise over the screen during the screening operation. This condition gradually improved until about 800 ft. from the outcrop a fair quality of coal was mined.

The plan of mining was to turn off entries to the right and left from the main line of development. The inferior quality of the coal found next the outcrop had the effect of deferring the opening of these side entries, but ultimately we turned off three to the left, the last one about 1,800 ft. from the outcrop. All of the three entries broke through on an area where the coal had been burned out entirely, at distances ranging from 350 to 500 ft. west from the main entry, and in each case our mine was flooded by the water confined in the caved material. No other entries have been driven to the left beyond the third left entry, so that the conditions beyond that entry remain undetermined.

In the first two cases when the water broke through from the burned-out area into our mine workings, it came in such volume that we were unable to approach the opening from which it issued. After the water had partly drained off we made an effort to reach and examine the opening from which it came and were at first prevented from approaching it by the efflux of black damp, which promptly extinguished a miner's lamp. This condition gradually improved as the flow of the water decreased; before it was fully discharged we were able to approach the opening, and

found that the pressure of the water had burst a hole larger than an ordinary barrel through a wall of coal several feet thick. Looking through this hole we saw quite an open space along a vertical wall of charred coal. The coal bed varies from 8 to 10 ft. or more in thickness. The roof of the bed on the west side of the mine is a massive sandstone of variable thickness which breaks in great rectangular blocks. At the point where we broke through the roof strata had been sufficiently strong to resist breaking close along the face of the burned coal, but had broken several feet back from the face, and between the great blocks of sandstone which formed the base of the caved material there were many vacant spaces. It was in these interstitial spaces that the water that flooded our mine had lodged. There was no means of deciding whether the fire that had consumed the coal bed had been extinguished from want of air and an influx of water had occurred later, or if it had been quenched by the water. There were no fine ashes visible as in the case noted in the Caledonian mine. They seemed to have been all washed out by the water. The greater part of the first flood was disposed of by siphon; the last two had to be pumped. We tried to use the mine water in a boiler to raise steam for the pump, but failed because it foamed so badly. We tried all the known remedies for foaming, but still it foamed. We sent samples of the water to three of the principal firms that advertise the treatment of impure water to fit it for boiler use. They all gave it up as being unfit for use. I give herewith an analysis of the water.

"Mineral Analysis"

	Grains per gallon
Silica.....	0.666
Oxides of iron and aluminum.....	1.576
Carbonate of lime.....	Trace
Sulphate of lime.....	83.952
Carbonate of magnesia.....	118.910
Sulphate of magnesia.....	303.989
Sodium and potassium sulphates.....	810.395
Sodium and potassium chlorates.....	14.960
Loss, etc.....	0.108
Total soluble solids.....	1,334.556
Suspended matter.....	3.971
Total soluble incrusting solids.....	509.093
Total soluble non-incrusting solids.....	825.463
	Pounds
Soluble incrusting solids per 1,000 U. S. gal.....	72.73
Soluble non-incrusting solids per 1,000 U. S. gal.....	117.92

"Contains a little over 1,334½ grains of solid matter in solution and a little less than 4 grains in suspension, per U. S. gallon of 231 cubic inches.

"This water is absolutely unfit to be considered as a boiler feeds supply, as it will not only cause the formation of a decidedly large amount of incrustation which will be exceedingly hard, impervious, persistent, tenacious and compact, but will also cause, under practically every condition, trouble in the way of foaming, priming, corrosion, pitting, oozing out at and causing leaky joints, destruction of gaskets, etc."

The water doubtless contains everything that was soluble in the coal ashes, besides the salts it accumulated in its passage through the strata overlying the coal bed. This all happened on the west side of the mine. It should also be noted that at a place about 2,000 ft. west of the opening along the burned outcrop there is a point that was considered a good place to open a mine when the development of the property was first considered. A pair of drifts were opened there on the plane of the coal bed and driven in 600 ft. or more, following a streak of ashes all the way, but as no coal was found the two drifts were abandoned. The present opening was then located. No unusual heat was noted when approaching the burned-out areas on either the east or the west side of the mine and the natural inference is that the fires which consumed this great body of coal are extinct.

On the east side of the mine the first drain entry was turned off about 2,000 ft. from the pit mouth and was driven eastward in the coal bed about 1,600 ft. to a gulch, where an opening was made to the surface. The outcrop between the pit mouth and this gulch is all burned out, and when rooms were turned off this entry and driven out toward the outcrop, in a short distance they all ran into inferior coal of the same nature as that found in opening the mine.

About 80 ft. vertically below the burned outcrop I have been describing is the place of the lowest coal bed in the formation, on the top of the basal sandstone. About 2 miles east of the King mine this bed is only a foot thick. Following the outcrop westward it increases in thickness to 4 ft. at the King mine and continues to increase until it shows about 6 ft. of coal a mile or more west of the King mine. This coal bed is nakedly exposed in many places along the outcrop. In view of the condition of the outcrop of the King coal bed I thought it remarkable that the lower coal bed showed no evidence of being burned on the outcrop for 2 miles or more on each side of the mine. The natural conditions to which they had been exposed for many years were identical and I could not imagine why one bed should have been burned by many fires of independent origin while the other had escaped ignition entirely.

I give herewith an analysis of both coal beds by Prof. William P. Headen.¹

¹ *Proceedings of the Colorado Scientific Society*, vol. viii, pp. 293 and 294 (1907).

Juanita, four and one-half foot seam. Specific gravity, 1.351.

PROXIMATE ANALYSIS		ULTIMATE ANALYSIS	
<i>Air-Dried Coal</i>		<i>Pure Coal</i>	
Moisture at 100°.....	2.175	Carbon.....	79.918
Volatile.....	34.447	Hydrogen.....	5.033
Fixed carbon.....	54.173	Nitrogen.....	1.813
Ash.....	9.205	Sulfur.....	0.968
		Oxygen.....	12.268
100.000		100.000	

Calorific value determined, air-dried coal, 7116 calories, 12809 B.T.U.; pure coal, 8080 calories, 14454 B.T.U.

Juanita, fourteen foot seam. Specific gravity, 1.318.

PROXIMATE ANALYSIS		ULTIMATE ANALYSIS	
<i>Air-Dried Coal</i>		<i>Pure Coal</i>	
Moisture at 100°.....	1.000	Carbon.....	82.920
Volatile.....	27.432	Hydrogen.....	4.479
Fixed carbon.....	66.863	Nitrogen.....	1.746
Ash.....	4.705	Sulfur.....	0.643
		Oxygen.....	10.212
100.000		100.000	

Calorific value determined, air-dried coal, 7674 calories, 13813 B.T.U.; pure coal, 8138 calories, 14648 B.T.U.

Coals with a high moisture and low carbon content are supposed to be the most liable to spontaneous combustion, but in this case it is the coal bed having a relatively higher moisture and lower carbon content that has escaped ignition at the outcrop.

Tracing the horizon of the King (burned-out) coal bed eastward along the north bank of the river, in 5 miles we reach the Somerset mine. The coal bed in which this mine is opened is identical with the King seam and has increased in this distance to double the thickness found in the King mine, but the lower part of the seam is so impure that only the upper half of it is mined. The Somerset mine is also opened to the north and developed by entries driven to the right and left. The entries driven to the left, with one exception, were driven a certain distance west and then had to be stopped on account of excessive heat. I am reliably informed that temperatures as high as 180° F. have been registered by a thermometer placed in a hole drilled in the coal in this hot area. In 1904, I visited the mine and saw miners wearing gloves to load coal because it was too hot to be handled with naked hands. There was a good current of air, but the temperature was 112° F. The last entry driven to the west, about 4,000 ft. in from the outcrop, seems to have succeeded in getting past the hot area, as temperatures as high as 140° F., registered by a ther-

monometer placed in a hole drilled in the coal, have gradually decreased to a normal temperature. The outcrop of the coal bed west of the mine is all burned. It is well above the level of the stream and an opening to the surface would be convenient and desirable, but every attempt to drive out to the surface from the interior of the mine has been frustrated by the heat.

On the mountain side above the area where the source of the heat seems to be located, about $\frac{3}{4}$ mile west of the mine and at an elevation of about 600 or 700 ft. above the coal bed, hot gases showing a temperature of 150° F. issue from rents in the strata. This phenomena was noted by the early settlers in the valley long before the mines were opened and the place was not inappropriately christened "Fire mountain" and is still known by that name. An analysis of the gas issuing from one of the crevices on the mountain was made by the U. S. Bureau of Mines (George A. Burrell, chemist) from a sample taken during 1911. The analysis shows: CO₂, 15.51; O₂, 3.29; CO, 0.00; CH₄, 0.23; N, 80.97; total, 100.00 per cent.

The cause of the abnormal heat in the Somerset mine and of the hot gases escaping from Fire mountain is generally believed to be the smoldering residue of an ancient crop fire, although one prominent member of the mining fraternity prefers laccoliths and thermal waters as a means of accounting for the phenomena.

With regard to the manner in which crop fires may originate, the suggestion that they may have been started by forest fires or camp fires built on a nakedly exposed outcrop seems to find more favor than any other mode of causation. While these causes have been in as active operation in the Eastern states as they have been in the Western, the difference in conditions may reasonably be held sufficient to account for the difference in results. I have traced the place or position of coal outcrops for long distances in Pennsylvania, West Virginia, in the western part of Virginia, and in other Eastern States without seeing any actual exposures of coal. Ordinarily the coal crop is covered with humid soil several feet deep, which forms a good protection to the coal bed from any surface fire. Naked exposures of coal beds are rare and I cannot recall seeing a burned outcrop in any of my examinations of coal fields in Eastern states.

In many places in the Western States the outcrops of coal are only partly concealed by a slight covering of soil and naked exposures along outcrops are frequent, and may show for several hundred feet at a stretch. The climate is arid and the vegetation scanty, consisting mostly of greasewood, sage brush, pinon and cedar trees, that will live with little moisture at any time but after a protracted dry spell become as dry as tinder and furnish good fuel for a fire. During nearly every summer for the past seven years I have seen trees on the north bank of the North

Fork of the Gunnison struck by lightning and burn fiercely until they were consumed. Some of these trees attain considerable magnitude, and it seems reasonable to believe that if one or more large burning pinon or cedar trees fell across the nakedly exposed outcrop of a coal bed sufficient heat might be generated to set it on fire.

That very slight differences in climate may create conditions more or less favorable to the ignition of the outcrop of coal beds is well shown in this neighborhood by comparing the north and south banks of the North Fork. The coal formation is exposed on both sides of the stream, and both banks rise abruptly 1,500 ft. more or less above the drainage level. The north bank receives the full force of the sun's rays nearly all day. There being little rainfall, the soil becomes so parched with the heat that it will support very little vegetation. The soil, what little there is, is loose and incoherent, and when rain does come it carries the loose soil with it to lower levels. When snow falls, it rarely lies on the ground more than one day; it melts and goes off rapidly; and the erosion from snow water is just as effective as that from rain, so that the rocks on the north side do not commonly accumulate any considerable covering of soil. On the other hand, the south bank is partly shaded from the sun, and does not receive the full force of its rays as the north side does. Snow lies nearly all winter on the south bank, melts gradually, and sinks into the soil wherever there is any soil to absorb it; vegetation has therefore a better chance to survive on the south bank. The vegetation holds the soil together so that the erosive action of the rainfall is not so great as on the north bank, and the rocks are more frequently clothed with a kindly covering of soil, which has the natural effect of making burned outcrops less frequent and not so extensive as they are on the north bank.

It is also worthy of note that on both banks where the outcrop crosses a gulch or drainage line of any considerable magnitude the coal is not burned out. This statement is not invariably true. The protection of the coal beds in the gulches is doubtless due to their being partly shaded from the sun, and the consequent accumulation of soil and denser vegetation, which restrains erosion, just as on the north bank.

If a coal bed lies under heavy cover and is burned out along the outcrop there is no possible means of determining by surface examination how far the fire has extended into the coal field, or of defining the limit of the burned-out area. The only surface evidence of the burning will be found in the calcined and charred rocks along the geological horizon of the outcrop of the bed, and in the fractured and displaced overlying rocks where the roof covering is shallow.

The rule stated is applicable to the burned-out areas adjacent to the Somerset and King mines, and under ordinary conditions will apply to coal beds of equal or lesser thickness elsewhere. The burning of a mam-

moth coal bed would be likely to form an exception to this rule, for obvious reasons.

The belief that crop fires do not extend far from the surface is responsible for the purchase as coal land of hundreds of acres of land that contains no coal, taxes being paid on it as coal land for a long term of years.

During the time the King mine has been in operation we have never received any complaints or heard any report of the coal having taken fire spontaneously when stored in large heaps, and at the mine on two occasions we had to unload and store slack in heaps 10 to 15 ft. deep, which lay undisturbed for several months without showing any signs of spontaneous combustion or even heating perceptibly; nor have I ever heard of any spontaneous fires in coal from the Somerset mine. But we have had three fires in the King mine from spontaneous combustion, which in each case originated in the *débris* from falls in the east side of the mine. In this part of the mine the deterioration of the coal bed already described extends so far in from the crop line and the roof of the bed is also found to be so much affected as to raise the suspicion that a coal bed not far above the one we are now working has been burned. This idea was strengthened by observing the structure of the roof, as soon as we had some falls in that part of the mine. I give a section herewith of the roof material in which the spontaneous fires were generated.

Massive sandstone.
White clay, 2 ft.
Coal smut, 1 to 2 ft.
Blue clay, 2 ft.
Coal, 1 ft.
Bone coal, 6 in.
Coal, 1 ft. 6 in.
Bone coal, 4 to 6 in.
Parting.
King coal bed, 10 ft. 6 in.

The strata above the parting forms the roof of the workings in the King coal bed. The coal found above the parting is all rather impure and contains much pyrites; even the clay when heated gives off strong sulphur fumes. The coal smut looks like coal that had been reduced to a fine powder and compacted just enough to hold together, but is easily crumbled to dust between the thumb and forefinger. It is the *débris* from this section of 8 or 10 ft. above the coal bed where the smut is found that generates spontaneous fires. The roof is difficult to maintain; when it breaks it comes down in small fragments and packs close.

Elsewhere in the mine where the smut is not found we have drawn a block of pillars. The roof was good, and when we had a break it came down in great blocks. On several occasions we noted that the temperature in these falls was several degrees hotter than in our return airways,

but the block of pillars was cleaned out without noting any temperature high enough to excite fear of spontaneous fire. Whenever we had a break in drawing pillars or a fall of rock of any considerable magnitude we commonly found on climbing up over the fall that as soon as we got a few feet above the level of the roof our lights were promptly extinguished. Whenever a miner comes in contact with gas that puts out his light he promptly labels it black damp. So it was in this case, but I noticed that this gas did not descend to the floor, even in the most isolated places where there was no air current. Consequently I concluded that the extinction of the flame in our lamps was due to some other gas. W. D. Scofield, of the U. S. Bureau of Mines, took samples of the air from the top of two of the falls and also from behind one of the stoppings where we had a fire walled off. These samples were analyzed by George A. Burrell and gave the following results:

Atmosphere from Walled-off Area.—CO₂, 3.62; O₂, 16.28; CO, 0.00; CH₄, 0.05; N, 80.05; total, 100.00 per cent.

Air on Top of Fall.—CO₂, 1.22; O₂, 16.60; CO, 0.00; CH₄, 0.25; N, 81.93; total, 100.00 per cent.

Air on Top of Fall.—CO₂, 1.30; O₂, 16.68; CO, 0.00; CH₄, 0.25; N, 81.77; total, 100.00 per cent.

It is remarkable that there is no CO in any of these samples, not even in the walled-off inclosure where the fire had been. Neither of the samples from the top of the falls, in which a light would not burn, showed enough CO₂ to extinguish a flame. The failure to support combustion in both cases seems to have been due to a reduction in the oxygen and a relative increase in the nitrogen content of the air. The decrease in the oxygen was probably due to slow combustion that did not generate enough heat to reach the temperature of ignition for the carbonaceous matter contained in the débris but doubtless caused the increase of temperature noted.

The burning of coal beds in place and the conditions which generate the fires that ignite them, as well as the spontaneous generation of fires in mines, is an interesting subject to the coal-mining fraternity and I have recorded my observations in the hope that it may prompt some other members of the craft to do likewise, as we have very little literature on the subject.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the New York meeting, February, 1914, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Apr. 1, 1914. Any discussion offered thereafter should preferably be in the form of a new paper.

Electric Traction in Mines

BY CHARLES LEGRAND, DOUGLAS, ARIZ.

(New York Meeting, February, 1914)

IN many iron, coal and copper mines where large tonnages are known before starting operation and proper provisions can be made, the problems of electric traction by trolley locomotives are not very different from those of surface plants. In such installations the gauge of the track, the radius of curves, and the clearances, both vertical and horizontal, can be made to suit the conditions of the traffic. It is more difficult to install electric traction in mines which were started with hand tramming and where no consideration was given to the possibility of mechanical traction being used. The writer having had some experience in the installation of electric traction in copper mines, the following remarks apply more particularly to these mines.

With the gauge of track usually 18 or 20 in., the weight limit of locomotives obtainable from manufacturers in this country varies from 3 to 6 tons. The full-load speed varies from $4\frac{1}{2}$ to 6 miles per hour. These locomotives, being made to run on very small radius curves, have a short wheel base and a long overhang from axle to coupling, which necessitates a coupling with a good deal of lateral motion to avoid derailling the cars on sharp curves, especially if couplings are of the standard railroad automatic type.

Although 3-ton locomotives will run on 12- or 16-lb. rails, it has been found more satisfactory to use 25-lb. rails, as the track keeps in much better shape, it is easier to maintain the bonding in good order, and fewer derailments from dirt on the track occur with the larger rails. Where 6-ton locomotives are used the 25-lb. rails are satisfactory, but 40-lb. rails have proved cheaper where the traffic is heavy and the ground is soft, as the track maintenance is considerably lower with the heavy rails. The locomotives will run on 15-ft. radius curves, but on through runs it is advisable not to go below 40-ft. radius.

The voltage used should not exceed 250 to 275 volts, and the trolley wire should be protected, to prevent accidental contacts, in front of chutes and at all points where it is low. With the air lacking somewhat in oxygen and the heat and high humidity prevalent in many mines, this

voltage, which is considered perfectly safe, has proved fatal in several instances and in such mines it is advisable to have a pulmotor available and men trained to use it in case of accident.

The trolley wire should be protected from dripping water and if the water is acid it must be protected; the writer has seen instances where a very small drip has cut a No. 00 trolley wire in less than three weeks.

The track bonding should be kept in good shape. This is one of the most difficult things to do, as most of the trackmen in the mines do not realize the importance of it. A badly bonded track will increase the repairs of motors considerably, as in passing from a dead rail to a live one the sudden rush of current is liable to form an arc across the motor commutator or from the commutator to the ground.

If the locomotive is not mounted on springs it has been found advisable to put the resistance grids on springs, with flexible leads to the controller, as on small locomotives the cast metal grids are light and very easily broken.

In a mine laid out for hand tramming the grade is generally made in favor of the loaded cars (this is also done to provide drainage for the mine), so that the load is fairly uniform going down with the loaded cars and coming up with the empty cars. This gives ideal conditions for a full load on locomotives at all times; but the motors on electric locomotives are seldom made so that the locomotive can deliver its full tractive effort continuously and this ideal operating condition leads to overheating of the motors and very heavy repairs unless the number of cars attached to the locomotive is kept down to the maximum that the motors can pull without overheating. This is difficult in practice, as it seems against human nature to run a locomotive of any kind with a load that does not slip the driving wheels when starting or at every point in the track where conditions are a little unfavorable. The difficulty of getting motors of sufficient size in the small space available with 20-in. gauge has obliged us in one or two instances where traffic is heavy and continuous to build our own locomotives, putting the motors above the wheels and gearing to the axles outside of the wheels. This makes a rather cumbersome design but allows the use of larger motors and has proved satisfactory in service. Even with this design the necessary clearance in the drifts limits the weight of locomotives to about 7 tons.

Where the tonnage to be handled is not great and yet mechanical traction is advisable a storage-battery locomotive is convenient. The running expenses are not much greater than with a trolley system, depending on the conditions under which the locomotive has to operate.

The Copper Queen Mining Co. operated a 3-ton storage-battery locomotive at Bisbee for over two years, under the worst conditions of any locomotive in their mines as regards track and curvature, and the results were better than the writer anticipated. To make use of one of the

regular locomotives, the battery, consisting of 150 Edison cells, was mounted on a separate trailer. This battery had a total output capacity of 40 kw-hr., the average voltage on discharge being 180 volts. The first trays furnished to hold the cells were of the regular type for automobiles and proved to have too small a clearance between cells. The hard bumping in switching combined with very heavy sweating (due to the locomotive going from very hot portions of the mine with moisture-saturated atmosphere to colder portions near the shaft) short circuited the cells externally. After the trays were altered to provide larger clearances and the cells were painted with insulating paint there was no trouble from this source, although two or three cells were lost in a bad wreck.

The power required at power station per useful ton-mile was approximately double that required with trolley locomotives, or 1.6 kw-hr., due to extra dead weight of battery car and lower efficiency of battery compared to trolley wire and track circuit, also to the losses in the motor generator used in charging the battery. With a locomotive designed to carry batteries the difference in power would be less. The power would also have been reduced if a motor controller had been used, grouping the cells in various combinations for starting, instead of a regular controller with starting resistances.

The traffic got too heavy to be handled with this locomotive and it did not run long enough to get figures on depreciation of storage battery. The maintenance of the battery-locomotive motor was less than on the trolley locomotive, but no exact figures are available. The capacity of the battery was approximately 50 useful ton-miles on one charge.

At the mines of the Copper Queen Mining Co., in Bisbee, the power used on trolley locomotives, measured at direct-current switchboard in power station, for the year 1912 amounted to 875 watt-hours per useful ton-miles. This amount, however, includes a few lights which are connected to the trolley circuit and gives too high a figure for the locomotives alone. It applies to cars with roller bearings, about one-half of the tonnage being carried in cars of 2 tons capacity and the other half in cars of 1 ton capacity. The conditions of the cars and track have quite an important bearing on power required per ton-mile, although the writer has no accurate figures. A rough idea can be formed from the fact that on a certain track in the mine of the Moctezuma Copper Co. one 3-ton locomotive cannot pull more than five cars of 20 cu. ft. capacity, equipped with regular Anaconda axles, without slipping the wheels, while the same locomotive pulls six cars of 22 cu. ft. capacity equipped with roller-bearing axles.

For the year 1912 the cost of various items in cents per useful ton-mile at Bisbee for a total of 408,000 ton-miles was as follows:

	Cents
Locomotive maintenance.....	2.95
Car maintenance.....	1.64
Track maintenance.....	5.24
Trolley maintenance.....	3.60
Power.....	1.64

Locomotive maintenance includes all electrical and mechanical repairs and replacements on locomotives, as well as lubricating oil and supplies.

Car maintenance includes all repairs, oil, and supplies on cars.

Track maintenance includes all track repairs and replacements, bonding, grading, and realignment.

Trolley maintenance includes all trolley-wire repairs and replacements, and repairs to protective trough around trolley wire.

Track and trolley maintenance are very heavy, due to shifting ground.

The cost of power (1.1 kw-hr. per ton-mile) is taken at the high-tension switchboard and includes the loss in transforming the alternating current into direct current.

In comparing power used by storage-battery locomotives and trolley locomotives it would be fairer either to compare the actual input into battery with direct-current power used by trolley locomotives or use the alternating-current power input to rotary converter in both cases.

In the case of the storage battery the input was approximately 1.28 kw-hr. per ton-mile, as against 0.875 kw-hr. for the trolley locomotive.

The figures for power on storage battery are based on two days' test and therefore are not as reliable as those on trolley locomotives, which cover a year's period.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the New York meeting, February, 1914, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Apr. 1, 1914. Any discussion offered thereafter should preferably be in the form of a new paper.

The Genesis of the Mercury Deposits of the Pacific Coast

BY J. ALLEN VEATCH, NAPA, CAL.
(New York Meeting, February, 1914)

THERE exists in the territory embraced between the summit of the Sierra Nevada and the coast a great dike and vein system that appears never to have been recognized in its entirety, and many facts concerning it have never been published. This is important, not only in affording numerous clues bearing on the origin, nature, and age of the mercury deposits, and eliminating many controverted questions, but it incidentally affords numerous facts bearing on the genesis of gold, copper, chromite, magnesite, dolomite, a type of calcite deposit, and numerous associated minerals. The mineral springs of the State almost without exception emanate from these dikes.

A great range of the hydrocarbons also exists throughout the entire system of these dikes. Seepages from their walls have frequently been mistaken as emanating from the inclosing sandstone and shale, resulting in heavy expenditures in the futile development of these Cretaceous beds, which contain no petroleum within the territory.

The theory of mountain making by lateral or tangential pressure is inconsistent with some of the following recorded facts.

The limitations of this paper do not admit of a description of each of the hundred or more mercury deposits embraced in the area, and therefore only typical examples will be described.

The accompanying map, Fig. 1, is not submitted as complete, or as entirely accurate, but it is as nearly so as the notes at hand will admit. The field is too extensive to be completely covered by a single individual.

The heavy continuous lines represent sections actually surveyed. The sections and extensions in dotted line are assumed, and are either unsurveyed, or buried under younger beds. There are numerous branches connecting the great parallels that the small-scale map does not admit of plotting, even if the survey had been complete. Likewise, the conclusions in some instances may be faulty, but it is to be hoped that as a whole they may serve as a foundation on which a more complete structure may be built in the future.

Geological Structure

There is much controversy as to the age of certain beds within the territory which cannot be entered into here. The pre-Cretaceous rocks of the Coast Range, varying greatly in character, are designated altogether as the "Basement Complex."

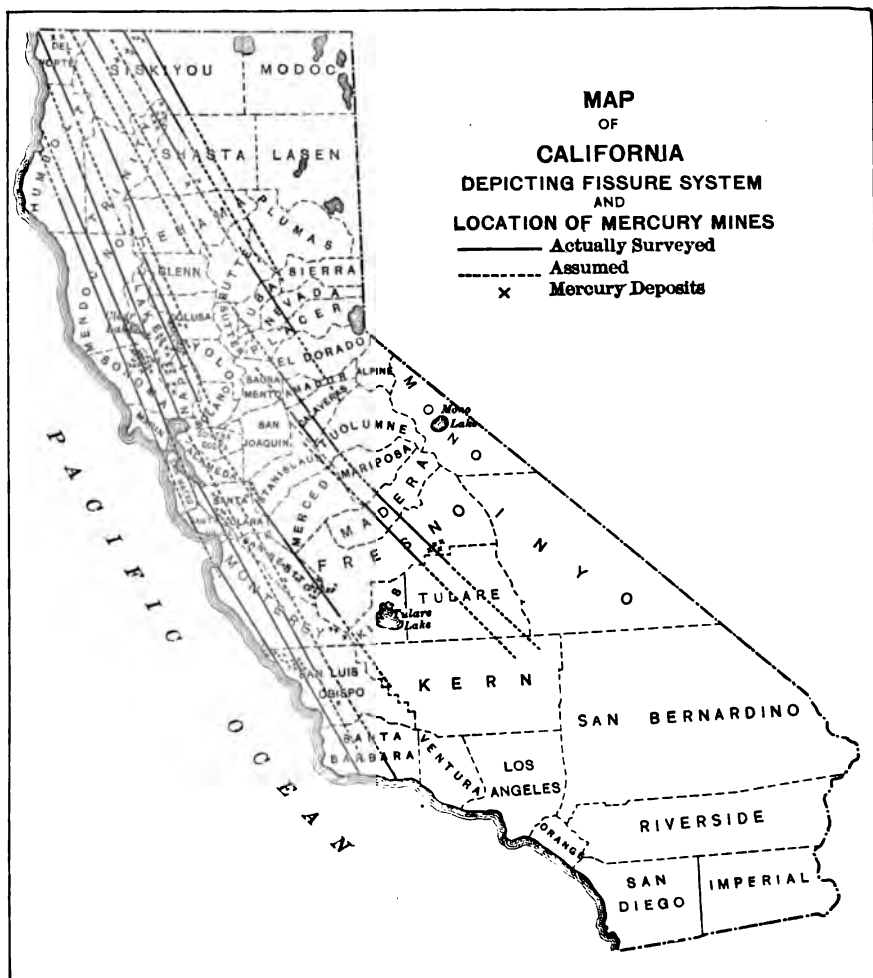


FIG. 1.—SKETCH MAP OF CALIFORNIA SHOWING FISSURE SYSTEM AND MERCURY MINES.

Resting directly on this is a limited series of shale, slate, conglomerate, and sandstone. Serpentine and chert have been described as belonging to it, but this is not a fact. Their universal characteristic is a

greatly disturbed and metamorphosed condition. This series will be designated as the "Metamorphic."

The next, or Lower Cretaceous, consists of alternating strata of sandstone and shale, with some conglomerate. It is divided into two sections, designated as the Knoxville, or Lower, and the Horsetown, or Upper. As they are continuous and conformable, they will be designated together as the "Shasta." The series attains a vast thickness, amounting

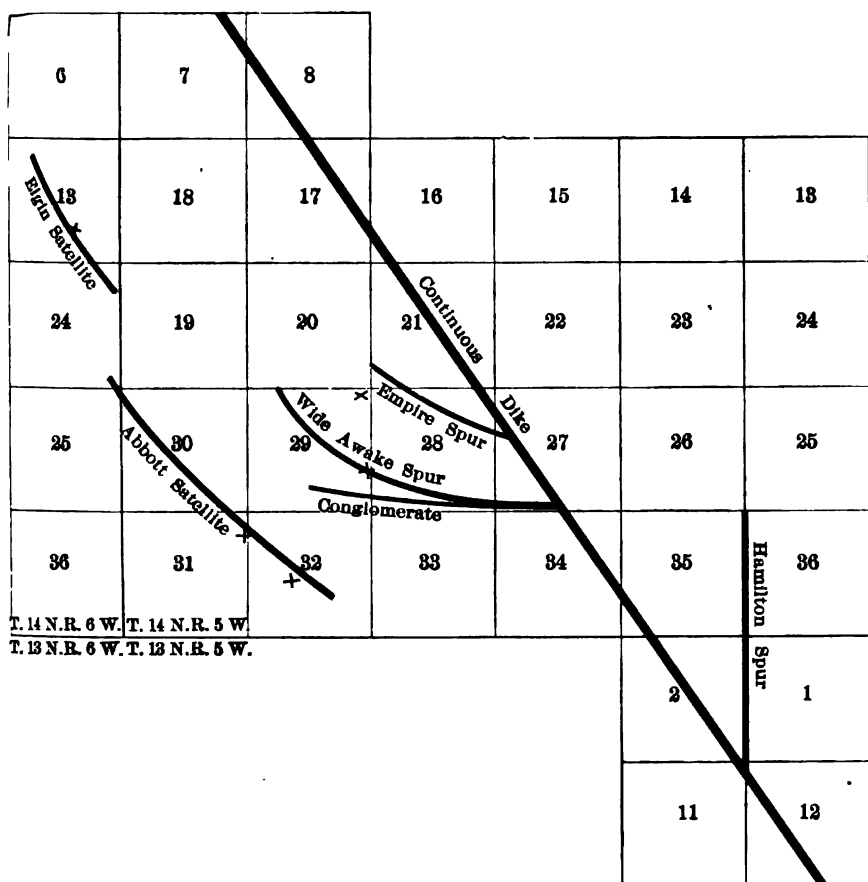


FIG. 2.—MAP OF THE SULPHUR CREEK, CAL., DISTRICT SHOWING DETAIL SECTION OF A TYPICAL SERPENTINE DIKE.

to 20,000 ft., in the northern part of the State, but tails off until the Basement Complex is exposed in many places directly north of San Francisco, and it exists only in patches south of San Luis Obispo county. It appears to have been laid down under the conditions of a gradually subsiding Cretaceous sea, deriving its detritus from erosion to the east and

north. It possesses uniform lithological characteristics that render it readily recognizable wherever encountered.

The area of the present Coast Range emerged at the close of the Lower Cretaceous, and along certain northeast-southwest zones was extensively crushed, plicated, and sheared, but on its east flank it was but little disturbed. The movements were attended by volcanic activity. One flow poured out from the vicinity of Mt. St. Helena, extended northward

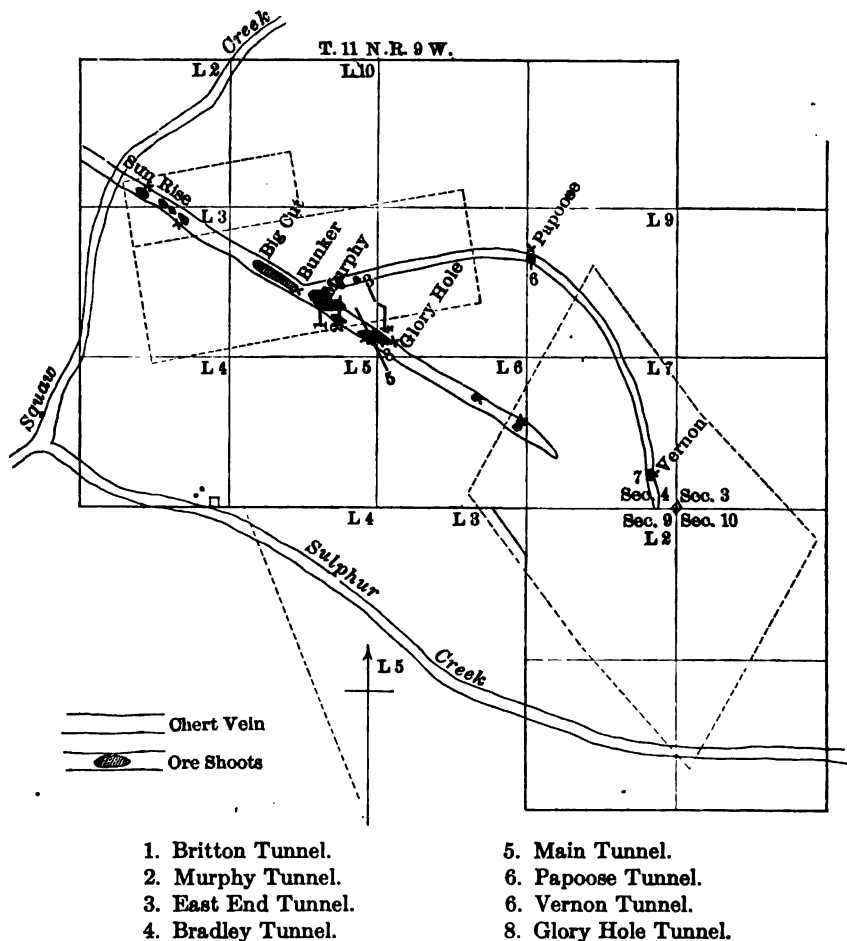


FIG. 3.—GEOLOGICAL MAP OF THE CLOVERDALE MERCURY MINE, SONOMA

to Middletown, Lake county, and southward to Vallejo, covering a distance of 60 miles.

This region was again submerged to receive the Upper Cretaceous, commonly designated the "Chico" beds. Like the "Shasta" the "Chico" attained its greatest thickness, 6,000 ft., in Tehama, tailing off

southward until it now exists only in small areas in the southern coast counties. It consists of shales and sandstones, usually of lighter color than the "Shasta," although the shale is sometimes nearly black. Both the shale and the sandstone are inclined to occur in thick sections rather than intercalated as is the case with the "Shasta."

Subsequent to the emergence at the close of the Cretaceous there were repeated oscillations and depositions throughout the Cenozoic. These were local in character within the region, and do not concern the present subject, except that they fix the age of certain lava flows by covering them. At the close of the Pliocene a basalt intrusion and flow took place all along the dike system. It was viscid magma, forcibly intruded as bosses, necks, tongues, and sheets. Its close association with the serpentine appears to be due to structural weakness along these lines. Silica, as hyalite, separated from this magma on cooling. They bear no other relationship to mercury deposition.

The final emergence marking the close of the Cretaceous involved all the territory north and west of the Sierra Nevada range, to some extent including the range, as well as the southwest quarter of the State of Oregon.

At the incipency of this oscillation, and while most of the area was at a horizon below sea level, there was produced a series of fissures, remarkable not only for their extent, but also for their general character and the associated mineral deposits. A dozen or more of these fissures were formed parallel to one another, with an aggregate width of between 5,000 and 20,000 ft., and an aggregate length of 3,000 miles, extending from Santa Barbara, in the south, far into Oregon, approximately conforming to the axis of the Coast Range and coast line, even to the bend northward at San Francisco. They are independent of the axis of the Sierras. The average strike of those in the Coast Range south of San Francisco is N. 36° W., and north of San Francisco, N. 23° W. The average for the southern section of the Sierras is N. 42° W., and for the northern continuation, N. 34° W. So tenaciously do these dikes hold to their individual strike that when one encountered the Mother lode at its southeast end it was not sensibly deflected, in spite of the great structural weakness of the older lode, and the fact that their respective strikes differed only by 7°. The dip may be in either direction, but never varying more than 30° from the vertical. The observed width varies from 70 to 5,000 ft. Many laterals connect the main parallels at sharp angles when the distance separating them is not great, and spurs frequently branch at varying angles, both north and west. These rarely extend more than a mile or two, and appear to follow pre-existing lines of weakness. In addition, there is a system of minor parallel dikes, varying from 1 to 3 miles in length, and rarely more than 1 mile distant from the continuous dike. That they are closely related there can be no

doubt. They will be termed "satellites." The accompanying map, Fig. 2, shows details of the Sulphur Creek dike. This is a typical section. The continuous fissures maintain a uniform strike and character regardless of the structure or character of the formation intruded.

Dike Material

The intruded material in the Coast Range dikes differs somewhat from that of the Sierra dikes. Generally serpentinization is more complete in the former. Where serpentinization has not destroyed the original structure, it is usually a light gray, ashy to flinty, soft pyroclastic, with inclusions of obsidian, a slightly basic glass. This rock has been described variously as "tuffoid," "tuffite," "opaline rock," "silica-carbonate sinter," "quicksilver rock," "caliche," etc. Lithologists have failed to provide a name. While it belongs to the tufa group, it is neither a tuffite nor a tuffoid. From necessity the local name, "caliche," will be adopted in this paper. Genetically, caliche resulted from the action of sea water on the ascending, purely igneous lavas, wholly free from water, while in a molten state.

The unaltered obsidian in smaller masses, spherical in form, exists as inclusions in the caliche, often sharply defined at the contact, but usually there is a gradation from one to the other. Apparently the obsidian was injected into the caliche as volcanic bombs. In some localities obsidian constitutes the vein filling completely along one wall, gradating into caliche at the other, indicating the exclusion of water from one wall.

Mt. Konocti must have existed at this stage as an island. Where the fissure crosses it great quantities of effusive obsidian were deposited.

The massive, intruded obsidian when in contact with the walls effected metamorphism, and was itself cracked by rapid cooling. The cores of the masses show incipient olivine crystallization, and often a fluidal structure under the microscope. This rock has been repeatedly described as "black opal" and accounted for as a replacement product.

The caliche, when pumiceous in structure, often has been silicified by later infiltrating solutions, and minor cracks in the obsidian also are sometimes filled with quartz.

The Sierra dikes have not been so carefully studied, but some sharp differences in their character are noted. Generally they are coarsely crystalline, basic rocks, incompletely serpentinized, and more compound, as if opened and intruded two or more times; satellites and spurs are absent, as also later silicification. Mercury deposits, also, are almost entirely absent; as are also the hydrocarbons. Generally they lack the characteristics resulting from the submarine environment, although the extrusive equivalent does not differ from that which flowed over the sea bed in the Coast Range.

Wall inclusions are everywhere found, especially in the Coast Range, sometimes in such large masses as to constitute a split in the dike.

Serpentinization

Serpentinization of the caliche is the prevailing condition, although there are considerable areas of intruded magma that have remained unaltered. The effusive magma appears to be invariably serpentinized. Serpentinization of one side of a dike, while the opposite wall remains unaltered, is a frequent condition.

Movement parallel to the outer wall between the caliche and the serpentine, due to reduction in volume of the latter, has resulted in contact phenomena. Serpentinization of the caliche is much more extensive and complete than of the obsidian, although the latter frequently shows alteration on the surface and on the walls of the cracks. This appears to be due to the less permeable character of the glass. It has been asserted that serpentinization of both the sandstone and the shale of the walls has sometimes occurred, but this unquestionably is a mistake. In the *Bulletin* (No. 27) of the California State Mining Bureau on the subject the microscope was employed to demonstrate this fact, but a more careful study of the specimen probably would account for it otherwise. Ten or more slides of sandstone taken from inclusions in serpentine, and from the walls in contact with it, failed to show any degree of alteration. It can be readily conceived that the cementing medium of the sandstone may be removed by solution, and replaced by infiltrated serpentine; but that silica under any condition could undergo serpentinization is improbable. The same may be said of calcite, dolomite, magnesite and other similar minerals. In short, serpentinization would seem to be confined to the basic silicates. A microscopic study of the crystallized intrusives of the Sierras shows that serpentinization progressed from the surface to the center of the individual crystals, and along the walls of microscopic cracks. Alteration was most advanced in the olivine and least in pyroxene. Where a serpentine fissure cut an older cross dike similar in character to those above described, the older one was highly serpentinized adjacent to the later dike, becoming less altered away from the contact, and at a distance of 100 ft. serpentinization ceased entirely.

From the foregoing, and much additional evidence, we are justified in concluding that serpentinization of these eruptives occurred promptly after deposition, and that the process ceased altogether when the condition changed.

Chalcedony

The next succeeding stage in the development of the system may be termed the "Chalcedonic." The depositing of chalcedony took place in pre-existing openings mostly resulting from a reassertion of the original

stress. The parting occurred generally along one or both walls of the serpentine: sometimes within the serpentine, and sometimes entirely within the wall. It is not so general in the satellites as in the continuous dikes. The chalcedony may persist for many miles along the wall, then disappear for long distances. It is often clastic and contains many inclusions from its walls, including serpentine. It also serves for a cementing medium for crushed rock, and for the silicification of porous material. That its deposition took place beneath the sea, at very high temperature, by hydro-thermal process, is certain. It is not auriferous and never exists as gangue of mercury ores, excepting in a few instances where it has been subjected to later crushing.

It has been suggested that chalcedony was deposited as a replacement of shale, but this could not be, as it occupies well-defined fissures, and is not always in the shale. Where it does occur in the shale the walls are not altered. Shale occurs as inclusions in it.

Chert and Mud Rock

The next succeeding stage is the chert and mud-rock deposits. These are contemporaneous, and as they contain inclusions of chalcedony the date of deposition is fixed as subsequent to the chalcedony. They are important as ore-bearing formations. The chert cannot better be described than by quoting from the *Bulletin* of the California State Mining Bureau on the subject: "The chert beds form a very characteristic member of this series, but are much more prominent in the districts north of San Francisco than in those south. They have been extensively discussed by Becker, Fairbanks, and Lawson. The first named refers to them as schistose rocks which have been subjected to a process of silicification, and classes them as phthanites. Blake supposed that they had resulted from the metamorphism of shales and sandstones by igneous action. J. S. Newberry (General Geology of California, page 66) says: 'Whether the material of which they are composed is thrown up from below, or, as is more probable, it is a metamorphosed form of the associated rocks, it is evident that the material has been subject to great heat.' Fairbanks (Bulletin Geological Society of America, vol. VI, page 71) classifies this formation as jasper. Lawson (15th Annual Report, U. S. Geological Survey, page 420) as Radiolarian cherts, which designation appears the most correct.

"The following is a concise statement of Mr. Lawson's study of this formation:

" 'These beds consist of alternate thin sheets of chert, ranging generally from one to four inches in thickness, only exceptionally having a much greater thickness, with partings of shale from one-eighth to one-half inch thick. Sometimes the regularity is much less marked, and in the less ferruginous varieties of the chert beds the sheets of chert assume occa-

sionally a lenticular form. The difference of opinion as to the proper classification of this formation is due to the fact that petrographically these cherts are not uniform. In many cases they are true jaspers; in others the silica is chiefly amorphous, and the rocks have a flinty character; in still other cases the proportion of iron oxide is so great that the cherty character disappears and the beds become locally very soft. All gradations between cherts composed almost wholly of amorphous silica, to those which are a holocrystalline aggregate of quartz granules, are found. The amorphous silica differs, however, from opal, in that it has a much higher specific gravity and contains much less combined water. The cherts are, then, minutely granular aggregates of crystalline silica, tending more toward the chalcedonic than to the quartz variety, with varying proportions of amorphous silica, mixed with ferric oxide and ferric hydrate, sometimes uniformly distributed, or again in patches or streaks. The mass is intersected by numerous small, often microscopical veins, the smaller filled with chalcedonic, the larger with quartzose silica, and occurring in two sets of fissures crossing at high angle. Zoisite is often found in the vein filling. These chert beds contain round or oval spaces, occupied by chalcedony, which are the residual casts of Radiolaria. The intervening shale consists of silica, iron, considerable magnesia, and a small amount of alumina without any clastic material. The association of chert beds with the sandstone precludes the possibility of their formation under deep-sea conditions, which would be indicated by the absence of fragmental material.'"¹

It may be added that usually, but not always, the banded chert exhibits fissure-vein phenomena, and is always in juxtaposition with the primary dike. It has been noted to occupy a vertical spur fissure connecting with the serpentine dike, as in Childs canyon, Napa county, and in a great fissure inclined 60° from the vertical at the Cloverdale mine. At the Twin Peaks it exhibits a bedded rather than a banded structure. A peculiar characteristic almost invariably exhibited is the accurate parallelism and uniform thickness of the bands. Where it occupies a straight and smooth wall in the shale the banding is correspondingly straight. Where the vent is irregular, with uneven walls, in the Basal Complex, the banding conforms to it. A section of one of these bands was noted to be missing in the Cloverdale mine over an area of several square feet. Presumably it had fallen from its position into the open fissure during the process of deposition. The next succeeding band bent sharply down over the broken edge and occupied the space of the missing band. This sharp offset was still plainly visible in the tenth succeeding band. The combination conditions of horizontal bedding and

¹ The Quicksilver Resources of California, Bulletin No. 27, *California State Mining Bureau*, p. 17 (1903).

vertical banding conform to the condition of a sea-floor abyss resulting from a mass of the wall gravitating into the open fissure, the abyss still retaining a flat and level floor. That it was deposited from deep-seated solutions vented along the walls of the original dikes is certain. These cherts are absent in the Sierras. They are never uniform.

The Cloverdale mine, in Sonoma county, may be cited as a fair example of this type of ore-bearing chert. Here the chert occupies a great fissure 80 ft. wide, with a northwest strike, and a dip of 30° from the horizontal. About half way along its exposed strike it is intersected at right angles by a branch 20 ft. wide, with a much steeper dip. This branch curves regularly, with a radius of about 2,000 ft., for 130° , then continues straight, approaching the major vein at an angle of about 50° , as shown on the accompanying map, Fig. 3. These veins fissure both the Basement Complex and the Chico which rests upon it.

A remarkable phase of the chert deposit exists at the Wideawake mine, in Colusa county. Here an east-west vertical spur fissure of considerable width and a mile in length is occupied by loose, almost perfectly rounded chert pebbles. It appears that during deposition of banded chert the process was interrupted, masses along the walls were shaken loose and broken, and at the same time water was injected upward from the bottom of the abyss sufficient in quantity and force to maintain the littoral in a state of ebullition. The rapid abrasion of corners produced pebbles, similar to the action of the "Devil's Tea Kettle," or that of a ball mill. At the same time a natural sizing occurred, removing most of the abraded material in the overflow. Toward the west end the pebbles are small and cemented; toward the opposite end they are larger and loose.

The Mud rock is but a phase of the deposit described above. Like the chert, it is a sea-floor deposit, containing both marine fossil and wall-fragment inclusions. As the mud rocks contain chalcedony inclusions their date is fixed as later. They appear to be contemporaneous with the chert. They exhibit more of the intrusive character than chert, because of their softness. In texture they vary from an impalpable mud to a fairly coarse sandstone, and are usually indurated by infiltrating solution. They exhibit typical jointing structure, but never bedding or banding. Sometimes they assume lenticular form, but usually the walls are parallel, sometimes for a mile or more in length. Generally they occur along the walls of the serpentine or chalcedony on the continuous dikes; sometimes they are within the wall, but never at a considerable distance from it.

The material comprising the mud rock was derived from attrition of the fissure walls in depth and conveyed upward by convection.

The Oceanic mine, in San Luis Obispo county, is a good example of this type of deposit. A massive intrusion of a fine-grained mud rock was itself fissured after solidifying, and a coarser-grained material of the

same character was intruded. This later intrusion so closely resembled sandstone that it has been repeatedly described as such even by trained observers. No sharp line of demarcation between the materials exists and the cross jointing is uninterrupted in passing from the one to the other. At the surface this fissure is entirely in Knoxville shale, parallel to and but a short distance from the chalcedony, but it eventually dips to the wall in depth, as it contains inclusions of the latter. The difference in character of the two intrusions may be accounted for by the attrition taking place at varying depths, and whether it was derived from sandstone or shale walls. Mercury does not occur as a contemporaneous deposit with this formation. Mud rock does not occur frequently along the satellites, neither does it appear to occur along the Sierra dikes.

The calcite-dolomite-magnesite deposits of a certain character belong to this class of deposits, and appear to be contemporaneous. These do not bear importantly on the genesis of the mercury deposits, beyond corroboration. The great deposits a few miles south of Hollister, in San Benito county, are good examples. These are five parallel satellites embraced within 3 miles. They are 2 or more miles in length, vertical, with a northwest strike. Their width varies from 50 to several hundred feet. They fissure the Knoxville shale, Chico sandstone, and Basement. The veins are connected irregularly by minor diagonals. The three middle fissures are occupied by nearly pure calcite, semi-marble in texture. A number of samples taken from these showed less than 3 per cent. impurities, and less than 2 per cent. was magnesia. The westerly fissure, otherwise of the same character, was occupied by dolomite, while the eastern fissure is a calcareous mud-rock vein containing 60 per cent. CaCO_3 .

The magnesite vein in Pope valley, Napa county, is similar in all characteristics to the Hollister calcite, excepting that the vein matter is nearly pure magnesite.

The completion of the last-described deposit closely coincides with the emergence of the Coast Range area from the Cretaceous sea, and may be properly described as the exact beginning of the Cenozoic. It was marked by a general crushing of the rocks within and adjacent to the continuous dikes; a milder form, and on a more restricted scale, of hydro-thermal and solfataric action; and the first deposition of metallic sulphides, gold, and quartz.

Deposition of Mercury

Quicksilver has been deposited almost entirely either as sulphide, Hg_2S_2 , or in the metallic state, the sulphide greatly predominating. It rarely occurs in combination with selenium, tellurium, and antimony,

and more rarely as iodide and chloride, oxide and amalgam. Cinnabar is deposited either alone, or together with a cementing material, which is almost invariably calcite or quartz; and rarely with magnesite, dolomite, aragonite, or anhydrite. It may be deposited either in the wall rock of any character, or in the dike or vein material; and in later inclusions and overlying sediments. Of the former, sandstone is by far the most common receptacle, because of its friable and permeable nature. It is least deposited in shales, because of their opposite qualities. Likewise serpentine, although closely associated with mercury deposits, never carries them to any great extent, because of its compact and impervious nature.

Cinnabar deposition takes place in pre-existing voids, rarely, if at all, as replacement, and occurs: (1) Filling open fissure veins, cracks, and interstices in crushed areas or zones with a marked tendency to form shoots. (2) Where the original rock has been removed by solution. This may be of a porous, cellular, or cavernous character. (3) In minute cracks or veinlets in chert, which appear to be due to shrinkage in volume due to a molecular readjustment; in obsidian and other later intrusions, due to a rapid cooling of the magma; and in compact serpentine where shrinkage was due to pseudomorphism. (4) In the joints of mud rock and chert. (5) Mixed with the residue of dissolved rock. (6) Mixed with clay gangue as an attrition product. (7) As placer concentrate. (8) As an original constituent of both intrusive and extrusive rhyolite. This latter has been observed in many places in British Columbia and Nevada but does not occur in the Coast Range.

Metacinnabarite, an allotropic state of cinnabar, occurs similarly in a great many localities.

Metallic mercury occurs intimately associated with cinnabar under variable conditions. It is present in perhaps 20 per cent. of the deposits of the coast. In proportion to cinnabar it increases with depth. It is found in the Socrates mine in voids in hard specimens completely sealed by cinnabar, proving it to be an older deposition. Some writers regard its presence as inexplicable. That it resulted from decomposition of the sulphides is most improbable, considering its stable character and existing conditions. It is equally unlikely that it could have entered into solution without combining with sulphur. On the other hand, it would appear entirely plausible that it should be driven into the zone of circulating water and to the surface by sublimation. Furthermore, there can be no doubt that the combined mercury was derived from this same source also. Mercury would readily reduce hydrogen sulphide in solution, combining with its sulphur, and would itself enter into solution, to be carried up and deposited on dilution and cooling. That this is a normal process was demonstrated by laboratory experiment by Prof. S. B. Christy many years ago. He appears to have experimented only

with the sulphide, but this does not affect the question, as the metal would readily combine with the sulphur derived from the hydrogen sulphide. On this subject Professor Christy writes: "The tests were made at temperatures varying from 200° to 250° C., and pressures varying from 260 to 500 pounds per square inch. The duration of the tests varied from three to ten hours, and in each case the cooling was allowed to take place gradually and undisturbed. Their result proved that waters containing solutions of alkali sulphides and some natural mineral waters to which sulphydric acid had been added, will, under certain conditions of temperature and pressure, dissolve mercuric sulphide; that increase in pressure aids rather than retards this solution, and that cinnabar is deposited from such solutions in the crystallized form when temperature and pressure are slowly lowered, while the occasional occurrence of metacinnabarite, or black amorphous sulphide of mercury, was explained by the sudden dilution or cooling of the depositing waters, or the local mixing, during crystallization, of agents causing rapid precipitation."²

The vapors of metallic mercury possess the peculiar quality of penetrating very compact rocks even to considerable depth, as is often the case in the walls of furnaces. It is slowly volatilized at atmospheric temperatures, but it will also condense in exit pipes, where the temperature must exceed 212° F. Cinnabar is very stable. Where it was used as a pigment in printing Egyptian mummy cases it remains perfectly bright to the present. Where its ores have been dissolved by sulphuric acid it remains as a residue. A discussion of the sublimation theory of mercury deposition is superfluous, but the following observation is of interest in this regard. At the Elgin Mine, in Colusa county, an attempt was made to refine sulphur by excavating a pit in the hillside, 20 ft. in diameter and 10 ft. deep. This was filled with crude sulphur and the top sealed. A vent was provided at the bottom, and the mass ignited. The idea was to use a portion of the sulphur for fuel to fuse the remainder, which could then be drawn off. The sulphur ore contained cinnabar. The heat of combustion cracked the walls to a depth of 5 ft. On the flat walls of these cracks, about 2 ft. from the pit, cinnabar was deposited in very large, but scattered, crystals.

At Kamloops lake, British Columbia, metacinnabarite occurs in a dolomite vein traversing the middle of a rhyolite dike in a very basic picrite, the dolomite being deposited on the walls toward the middle of the latest fissure. Before it was completely filled mercury began to deposit with the dolomite, and toward the final stages mercury was exclusively deposited. This process was exactly duplicated 10 miles east of Round mountain, Nevada, excepting that the country rock is granite.

² Quicksilver Resources of California, *Bulletin No. 27, California State Mining Bureau*, pp. 30-31 (1903).

Oil as a Precipitant

Because of the frequent presence of some of the hydrocarbons in quicksilver ores, it has been suggested that it may have acted as a precipitant for the latter, but there is no reason for believing this was the case. Cinnabar is commonly observed replacing marine calcareous fossils in mud rock, and it showed decided affinity for partly carbonized tule root in the Cache Lake bed at Sulphur Bank. On the other hand, rich ores commonly are not associated with oil, and in the foregoing quotation by Professor Christy it is shown that deposition occurred independent of a precipitant.

With four unimportant exceptions mercury deposits are confined to the Coast Range. Mercury deposits occur almost exclusively in the satellites, and the satellite is not a pronounced characteristic of the Sierra dikes; neither is the commonest mercury gangue—viz., chert, lime, and mud rock. Limitation to shallow depths is a pronounced feature of mercury deposits. By far the greatest proportion of them did not reach 300 ft. Very few attained the depth of 1,000 ft., and only two exceed this. Only one approached the 2,000-ft. mark.

Age of Deposition

Unquestionably, deposition of mercury began immediately on the emergence from the Cretaceous sea. It has continued in a lessening degree, having taken place in Eocene sandstone at the Lehman mine at San Luis Obispo; and in basalt which caps the Upper Pliocene at Sulphur Bank; and at the last-named place it is at the present slowly depositing in waste dumps. In connection with this it is interesting to note that at the Abbot mine, in Lake county, in a minor fissure about 8 ft. wide, and at a depth of 80 ft., a group of seven fossil shells was found inclosed in caliche and very near obsidian intrusions. These consisted of a *Turrilites catenatus* and six half *Rhynchonella whitneyi*. These were siliceous. The *Turrilites* when broken across the base showed the interior to be transparent crystallized quartz, with inclusions of small cubes of iron sulphides. Calcareous fossils of this kind are abundant on the surface in this vicinity, and probably they were fossilized at the time they were precipitated into the plastic caliche magma of the fissure. These fossils are generally considered as belonging to the late Shasta, but in this district they rest on the surface and not in the Lower Cretaceous, and may belong to the base of the Upper.

Associated Minerals

The minerals so frequently associated with mercury deposits as to indicate genetic relationship may be classified under four heads: (1) Those incorporated in the original magma or injected into it as bombs

while in a plastic state. (2) The purely hydro-thermal deposits. (3) Those resulting from later alterations and reaction. (4) The hydrocarbons derived from organic material precipitated into the fissure from the sea, and incorporated with the magma by convection.

(1) Of the first class, in addition to the obsidian previously referred to, chromite is common throughout the length of all the dikes. Metallic copper and its alteration products (especially bornite) are not uncommon. Many years ago a small furnace was erected in the western part of Colusa county for the treatment of ore derived from this source. A piece of silver weighing about 10 oz. was found in this locality by a local resident. Notwithstanding it was malleable and ductile and apparently free from sulphur or other compound, it had been broken across, fracturing along crystalline cleavage planes. The crystallization was apparently due to slow cooling. It may have been a definite alloy. The specimen was not available for further examination.

Platinum and its associates, iridium and osmium, in many if not in all instances, were derived from this source. It is of interest that platinum associated with chromite occurs in serpentine in the Russian Urals.

The question here asserts itself: Were not the hydro-thermal copper deposits originally derived from bombs injected into the zone of circulating waters? Excepting in the northeast corner of the State all the copper is closely associated with the serpentine dikes.

In some localities garnets are common constituents of the serpentine, and diamonds found sporadically throughout the State may be traceable to it.

(2) *The Hydro-thermals.*—Besides the earliest chalcedony, discussed in the previous pages, quartz and limestone are the most abundant as vein fillers and cementers; and dolomite and magnesite frequently form large deposits. Common, but less abundant, are aragonite, opal forms of silica, agate, sinter, and anhydrite. Of the copper ores usually deposited with a quartz gangue are azurite, malachite, bornite, chrysocolla, chalcopryite, malaconite; other copper minerals occur more rarely.

Gold intimately associated with cinnabar occurs in a number of places, besides occurring independently of it along the dikes north of San Francisco. The Manzanita mine, in Colusa county, was originally operated as a gold mine, and later exclusively as a quicksilver mine. In one deposit the gold occurs in the jointing and veins of the Basement Complex without gangue and intimately associated with petroleum. In another, a small horizontal very rich quartz vein crossed vertical, metamorphic Knoxville sandstone. In a third, auriferous crystallized quartz filled interstices in a crushed zone of the Basement. All of these deposits plainly were derived from vents along the serpentine dike. Six miles northeast of these deposits, on the contact of the same dike at the Clyde mine, a chimney formed in crushed slate of the Metamorphic Bed. It was very

rich at the surface, but gradually became impoverished and ceased at a depth of 80 ft. Quartz gangue was deposited with only a part of the gold. The Keely deposit consisted of a pile of sinter float, some pieces weighing a ton, together with from 1 to 3 ft. of auriferous mud, all lying on extrusive serpentine, but within a very short distance of the dike wall. Together with the other sinter float were a number of tubes, or cylinders, and fragments of them, the inner surfaces of which were lined with gold. These were built up by geyser ejectments like the Bee Hives of the Yellowstone. Specimens of these can be seen at the museum of the California State Mining Bureau. The interesting feature of this is that the latest ejected solutions were especially rich in gold. The auriferous cementing silica of the adjacent described deposit appears to have been derived from this source.

At the Elgin mine a concentrating plant for cinnabar recovered considerable gold as a by-product. At the Abbot mine the cinder dumps remaining from the treatment of thousands of tons of ore carry an average value of \$2 per ton in gold. This was derived from quartz stringers in obsidian intimately associated with petroleum.

It is not within the province of this paper to discuss the genesis of auriferous deposits of the Mother lode, but it is of interest to note that many of these deposits toward the south are in close proximity to the serpentine dike. In the famous Rawhide mine, in Tuolumne county, gold was deposited in, or rather on the face of, the serpentine at the contact.

Incidentally, this fixes the age of the auriferous deposition as Eocene. The question is insistent: If the mercury and copper were derived from injected magma, why not the gold as well?

Pyrites and marcasite are common minerals, and stibnite is met with in a few mines. This is surprising considering that it is inseparably associated with cinnabar in the rhyolite of Nevada and British Columbia. A few other metallic ores occur with cinnabar but in small quantities, notably nickel, lead and zinc are conspicuous for their absence.

(3) The third class is of but little importance. Serpentine as a pseudomorph has been fully discussed. Sulphur as superficial deposits is very common in quicksilver mines. This results from the decomposition of sulphuretted hydrogen. Free H_2SO_4 (sulphatiti) is commonly encountered in mines, and is also derived from the same gas. Through the action of the acid on lime, soda, magnesia, and alumina, their respective sulphates are common. Epsomite will grow on the walls and floors of abandoned workings until the capillary crystals will attain yards in length, resulting in a billowy mass almost filling a drift. Hematite and limonite are everywhere conspicuous by their color in the adjacent walls rather than in the serpentine. Oxidation products of chrome are sometimes observed. Potassium salts are almost invariably present

in the mineral waters, and frequently the borates. Silicification of wood in the vicinity of extinct geysers is common in the Coast Range.

(4) *The Hydrocarbons*.—So perfect has been the natural process of fractional distillation that a very large number of the definite hydrocarbons have been segregated. These range from the methane (fire damp) which commonly emanates from mines to black, hard, vitreous, pliable, elastic, oily, waxy and gummy varieties.

In addition to the common combinations of these elements a number of rare combinations have been noted: For instance, aragotite in the form of bright yellow scales from the New Almaden and Redington mines; its formula is not given. Napalite, C_3H_4 , a waxy bituminous substance. Posepnyte, $C_{22}H_{36}O_4$, found in plates and nodules of a dirty, light green color at the Great Western mine. Idrialite, $C_{42}H_{14}O$, from the New Idria mine. Ichthyol is contained in the waters of Adams springs, and gives it the odor resembling kerosene.

An occurrence of oil worthy of note is at the Abbot mine. Siliceous bubbles occur in vugs in quartz seams. Their diameter varies from $\frac{1}{8}$ to $\frac{1}{4}$ in. and coincides with the minor diameter of the vug. These were of quartz, perfectly spherical, resembling soap bubbles, with walls no thicker. When broken they were found to contain light distillate, while the remainder of the vug was occupied by a heavier petroleum. Similarly, at the Manzanita mine the siliceous bubbles were enveloped in bitumen. Geodes described as egg-shells containing oil and sulphur are reported from the New England mine.

In some sections of the serpentine dikes sufficient petroleum has accumulated to penetrate the sandstone wall for considerable distances. The theory that this oil originated from organic matter precipitated into the open fissure is supported by the fact that the Sierra dikes do not contain oil. It is known that this region rested above sea level during the period of fissuring.

Orogenic Considerations

That the plicating of the present Coast Range resulted from lateral pressure cannot be refuted, but that the Cretaceous uplift, or at least the incipient stage of it, was due to a wholly different cause appears certain. Lateral compression could have had no part in the uplift accompanied by fissuring of the character and extent of the serpentine dike system.

The entire region including the Sierra Nevada and the Coast Range and the great intervening valleys of Sacramento and San Joaquin was involved at the incipient stage of the Cretaceous uplift. It was at this stage that the serpentine dikes were created. The coast dikes were opened continuously from Santa Barbara to Eureka, a distance of over

500 miles. They were opened to an aggregate width of from 5,000 to 20,000 ft., and occupied by magma of low viscosity. That the uplift resulted from pressure of the molten interior exerted on the rigid crust conforms to all existing conditions, with one insistent exception.

The distance between the extreme eastern and western dikes, at right angles to their strikes, is 150 miles. This may be designated the fissure zone. The actual uplift was probably 200 miles in width. Assuming the zone to be a plain 200 miles wide, and allowing the extreme uplift of 5,000 ft.—which is excessive—the increase in distance across the zone, resulting from the arching to that extent, amounts to but 70 ft., which would be represented by that width of fissure, while the actual requirement to conform to the conditions is from 5,000 to 20,000 ft. There is not the slightest evidence of fusing or replacement of the dike walls.

There is nothing to indicate forcible intrusion, but every evidence that the magma simply swelled up, occupying the open fissure. Flowage of the walls in the Coast Range did not occur.

The satellites are equally inexplicable, occurring as they do parallel to and in close proximity to the continuous dikes. With only a mile of length, they may attain a maximum width of 80 ft. without showing crushing or shearing perpendicular to their strike, as might be expected. Gravity had no part in their creation. The fissuring process apparently extended over a considerable period. Probably the satellite resulted from a mild assertion of the stress at the beginning, which later rent the crust continuously for such a great distance.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the New York meeting, February, 1914, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Apr. 1, 1914. Any discussion offered thereafter should preferably be in the form of a new paper.

The Heat Treatment of Steel Castings

BY C. D. YOUNG, O. D. A. PEASE, AND C. H. STRAND, ALTOONA, PA.

(New York Meeting, February, 1914)

IN an effort to employ cast steel of a stronger structure than that found in the annealed steel castings, the possibilities of heat treatment which will increase the strength without materially decreasing the ductility may be resorted to.

The following abstracted report (which is a brief outline of what has already been done by the Pennsylvania Railroad Co. at its shops and Test Laboratories at Altoona, Pa.) is of material interest, as it indicates what may be done with steel castings when properly treated, thereby permitting in railway service greater strength of cast steel parts without any increase in weight or space.

The question of the heat treatment of alloy steel castings is not taken up in this paper.

The obscurity formerly surrounding the heat treatment of steel has been for the most part removed by the development of our knowledge of the critical points of steel, pyrometers, furnace construction, and the testing of the finished product.

The operations of the heat treatment proper will be taken up under the heads of (1) heating for quenching; (2) quenching; (3) drawing.

(1) *Heating for Quenching*.—Heating for quenching is best conducted slowly, especially in the case of castings of variable thickness. Cracks may occur either in heating or in cooling, due to different temperatures at different points of the casting. The castings should be thoroughly soaked at the maximum temperature (generally 1,500° to 1,600° F.), 1 hr. being sufficient for sections 1 ft. in thickness. The minimum temperature which will produce the desired hardening effect will, in all cases, be found to be the most satisfactory, as the grain coarsens when the critical range is exceeded to too great an extent. All temperatures should be governed by a checked pyrometer with the hot junction to the heated object, and with several couples in a large furnace to insure a uniform temperature.

(2) *The Quenching Operation*.—The casting should be transferred as quickly as possible from the furnace to the quenching bath, and in the case of large castings, such as locomotive frames, this is by no means a

simple matter. The larger castings are best handled by means of cranes and rollers.

The quenching agent employed is generally water or oil, preferably the former, because of its cheapness and drastic cooling effect, more readily breaking up the coarse cast-steel grain. With intricate castings it is generally best to use oil. With water, it is possible to have a large tank and a large running stream, serving to maintain a uniform temperature. Castings should never be thrown in to rest on the bottom of the tank, but should be agitated to prevent the formation of a coating of vapor, retarding the quenching effect. It is also best, whenever possible, to quench the thicker portions first.

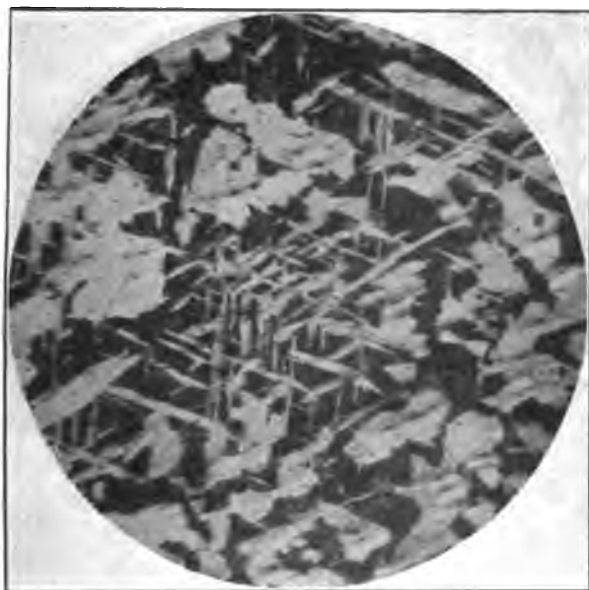
(3) *The Drawing Operation.*—Whenever possible, the drawing should be done in a bath of some kind, such as lead, barium chloride, a barium chloride-salt mixture, or oil. In the case of large castings this is manifestly impossible, and great care should be exercised in obtaining a uniform temperature in the drawing furnace.

The use to which the casting is to be put determines the drawing temperature, railroad work, by reason of the shock and vibration of the road, requiring high ductility at the sacrifice of some strength.

The results of some tensile, chemical, and micrographic tests of commercially annealed and experimentally heat-treated cast steel bolsters accompany this paper. The following table shows the heat treatment and the results of tensile and chemical tests:

	Commercially annealed				Heat treated			
Bolster No.....	B43	B18	B2	B29	B10	B39	B15	BB
Elastic limit, pounds.....	30,950	36,700	36,070	41,990	44,663	61,940	61,390	54,930
Ultimate strength, pounds.....	57,610	78,665	74,020	69,783	80,393	87,890	92,750	84,290
Elongation in 2 in., per cent.....	14.8	6.0	12.3	5.3	13.2	4.3	11.7	17.3
Reduction of area, per cent.....	26.8	4.5	16.0	5.9	19.0	7.7	15.4	27.3
Analysis								
Carbon, per cent.....	0.31	0.51	0.35	0.49	0.32	0.33	0.33	0.30
Manganese, per cent.....	0.82	0.68	0.63	0.70	0.62	0.88	0.76	0.62
Silicon, per cent.....	0.34	0.31	0.36	0.34	0.26	0.41	0.37	0.36
Phosphorus, per cent.....	0.016	0.045	0.036	0.036	0.042	0.014	0.041	0.032
Sulphur, per cent.....	0.010	0.030	0.016	0.042	0.030	0.025	0.029	0.018
Heat treatment								
Annealed at, F.°.....	1,500	1,550	1,550	1,550	1,580	1,640	1,600	.....
Quenched in water at, F.°.....					1,600	1,600	1,600	1,600
Drawn to, F.°.....					900	900	900	900

Examination of the accompanying photomicrographs, Figs. 1 to 8, inclusive, shows the inefficiency of the manufacturer's annealing, which is by no means uncommon. The contrast between the annealed samples and the treated samples is readily apparent. Figs. 1 and 3 show a coarse needlelike ferrite formation, traces of the casting structure, not obliterated by annealing. Figs. 2 and 4 show the structure of some



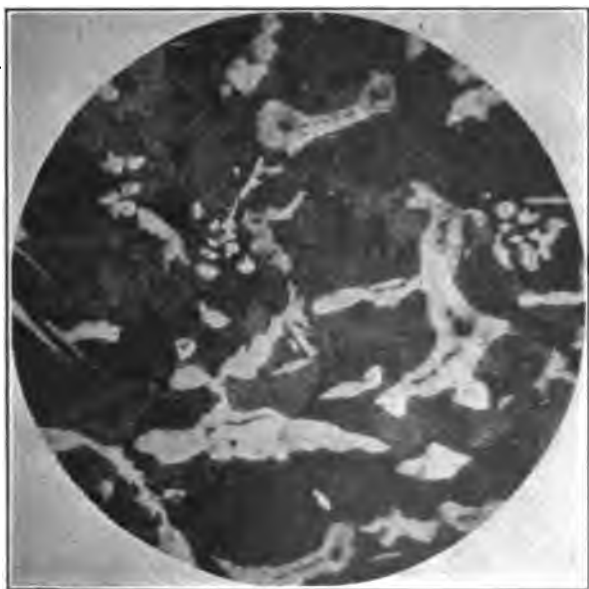
Magnification 100 diameters. Etched with picric acid.

FIG. 1.—No. B43. COARSE NEEDLE-LIKE FERRITE STRUCTURE, INDICATING POOR ANNEALING.

CAST-STEEL BOLSTERS, COM-MERCIALLY ANNEALED

Physical Test

	B43	B18
Ult. str., lb.		
per sq. in.	57,610	78,665
Elas. lim., lb.		
per sq. in.	30,950	36,700
Red. of area,		
per cent.	28.8	4.5
Elong. in 2		
in., per cent.	14.8	6.0



Magnification 100 diameters. Etched with picric acid.

FIG. 2.—No. B18. COARSE HIGH-CARBON STRUCTURE. THE FER-RITE IS SEGREGATED IN LARGE AREAS.

Chemical Analysis

	B43	B16
Carbon....	0.31	0.51
Manganese ..	0.82	0.68
Silicon	0.34	0.31
Phosphorus .	0.016	0.045
Sulphur	0.010	0.030

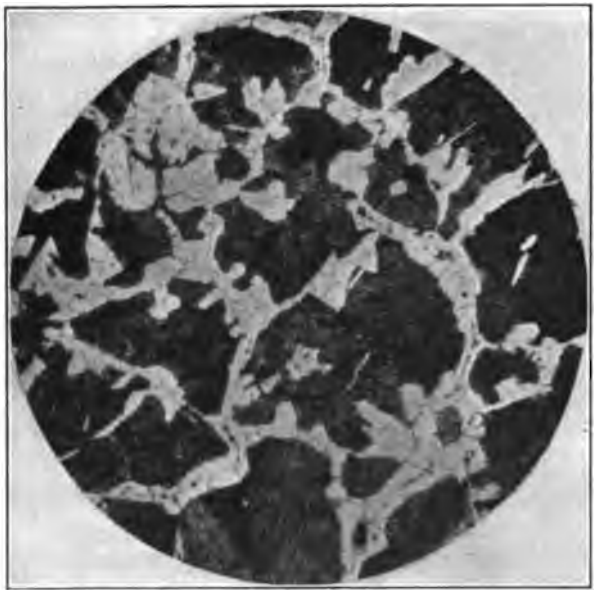
Heat Treatment

Annealed at..... 1,500° F.



Magnification 100 diameters. Etched with picric acid.

FIG. 3.—No. B2. COARSE NEEDLE-LIKE FERRITE STRUCTURE, INDICATING POOR ANNEALING.



Magnification 100 diameters. Etched with picric acid.

FIG. 4.—No. B29. COARSE HIGH-CARBON STRUCTURE. THE FERRITE FORMS A THICK NETWORK.

CAST-STEEL BOLSTERS, COM-MERCIALY ANNEALED

Physical Test

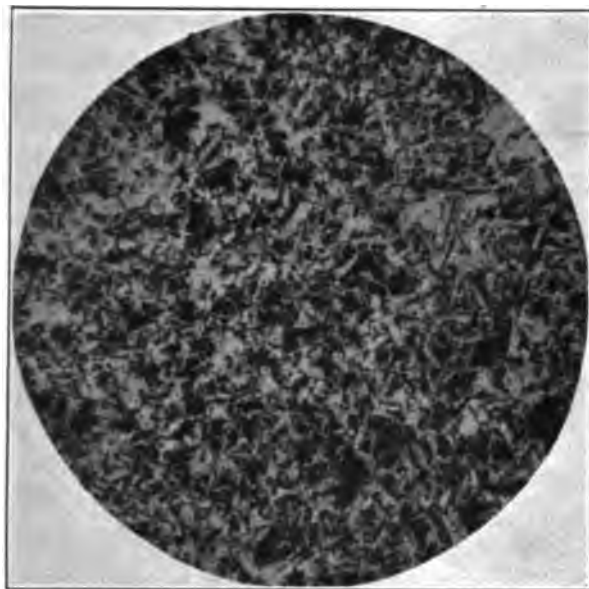
	B2	B29
Ult str., lb.		
per sq. in.	74,020	69,783
Elas. lim., lb.		
per sq. in.	46,070	41,990
Red. of area,		
per cent.	16.0	5.9
Elong. in 2		
in., per cent.	12.3	5.3

Chemical Analysis

	B2	B29
Carbon . . .	0.35	0.49
Manganese . .	0.63	0.70
Silicon	0.36	0.34
Phosphorus . .	0.036	0.036
Sulphur	0.016	0.042

Heat Treatment

Annealed at 1,550° F.



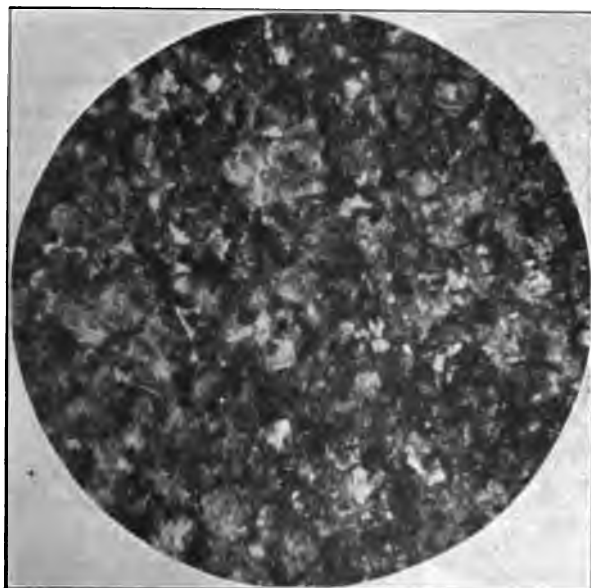
Magnification 100 diameters. Etched with picric acid.

FIG. 5.—No. B10. GOOD HEAT-TREATED STRUCTURE. THE LARGE AMOUNT OF FERRITE LENDS DUCTILITY.

CAST-STEEL BOLSTERS, HEAT-TREATED

Physical Test

	B10	B39
Ult. str., lb.		
per sq. in.	80,393	87,890
Elas. lim., lb.		
per sq. in.	44,663	61,940
Red. of area,		
per cent.	19.0	7.7
Elong. in 2		
in., per cent.	13.2	4.3



Magnification 100 diameters. Etched with picric acid.

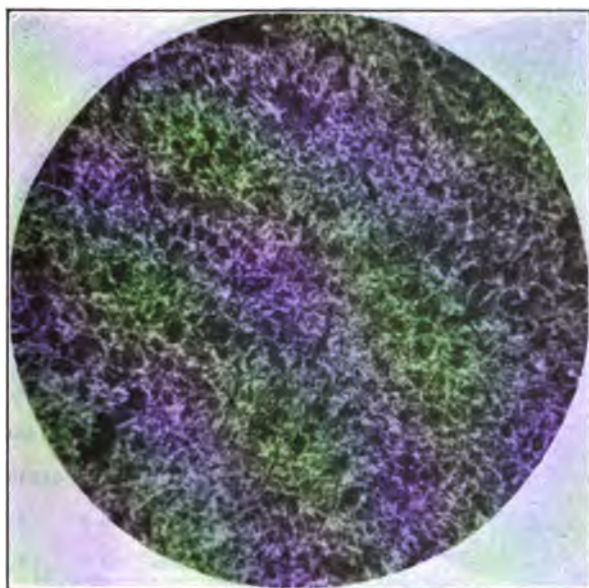
FIG. 6.—No. B39. SHOWS TOO LITTLE FERRITE, GIVING LOW ELONGATION.

Chemical Analysis

	B10	B39
Carbon	0.32	0.33
Manganese . .	0.62	0.88
Silicon	0.26	0.41
Phosphorus . .	0.042	0.014
Sulphur	0.030	0.025

Heat Treatment

	B10	B39
Annealed at . .	1,580	1,640
Quenched at . .	1,600	1,500
Drawn to . . .	900	900



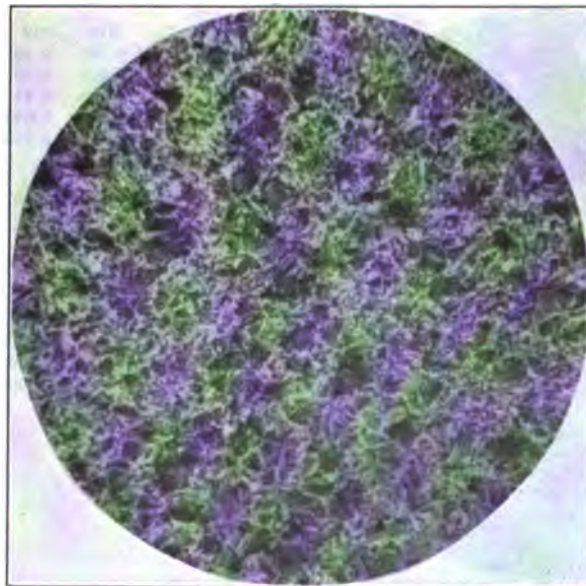
Magnification 100 diameters. Etched with picric acid.

FIG. 7.—No. B15. GOOD HEAT-TREATED STRUCTURE, SHOWING SMALL FINE FERRITE NETWORK.

CAST-STEEL BOLSTERS, HEAT-TREATED

Physical Test

	B15	BB
Ult. str., lb.		
per sq. in.	92,750	84,290
Elas. lim., lb.		
per sq. in.	61,390	54,930
Red. of area,		
per cent.	15.4	27.3
Elong. in 2		
in., per cent.	11.7	17.3



Magnification 100 diameters. Etched with picric acid.

FIG. 8.—No. BB. GOOD HEAT-TREATED STRUCTURE, SHOWING SMALL FINE FERRITE NETWORK.

Chemical Analysis

	B15	BB
Carbon	0.33	0.30
Manganese . .	0.76	0.62
Silicon	0.37	0.36
Phosphorus . .	0.041	0.032
Sulphur	0.029	0.018

experimental high-carbon bolsters, which are not sufficiently ductile. Figs. 5, 7, and 8 show excellent heat treated structures, with a very fine ferrite network. Fig. 6, while given the same heat treatment as the others, shows very little free ferrite, checked by the low elongation of the tensile test. This may be due to the high manganese and silicon content. The heat treatment of these castings would have been more satisfactory with a drawing temperature of 1,100° F. instead of 900° F.

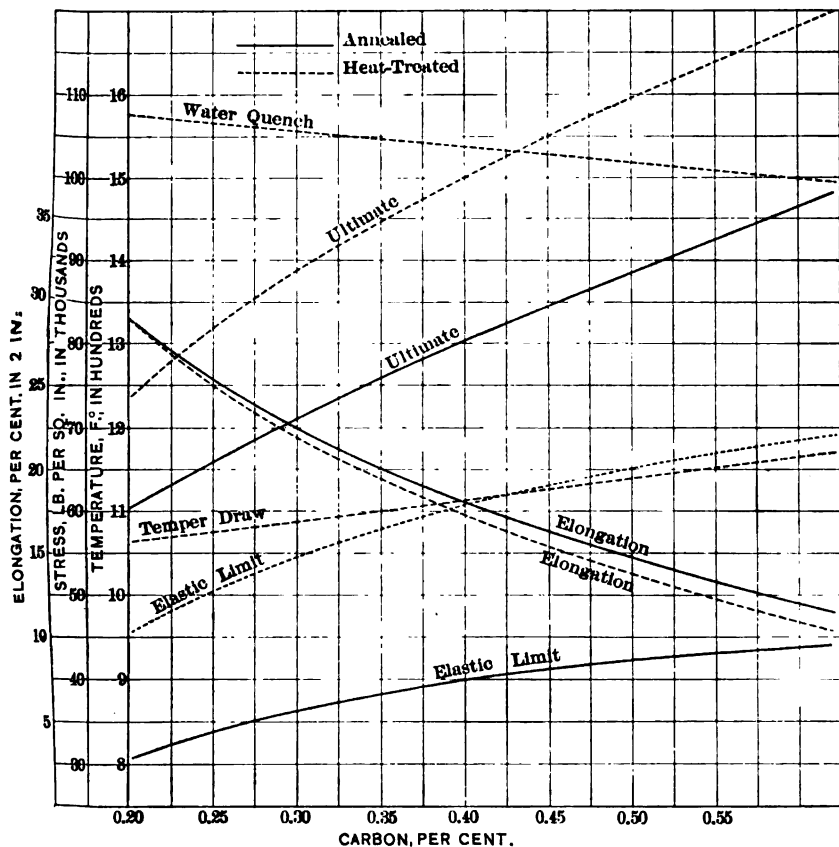


FIG. 9.—AVERAGE RESULTS OF TENSILE TESTS.

The plot, Fig. 9, shows the average results of a considerable number of tensile tests made from large castings. It will be observed that the heat treatment increases the elastic limit about 50 per cent. and the ultimate strength about 25 per cent., without any material change in elongation. The heat treatment to produce these results is also shown in the plot. In the event a fair amount of ductility is required, it is not desirable to have the carbon content above 0.35 per cent. Individual results will vary from 5 to 10 per cent. from the average results.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the New York meeting, February, 1914, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Apr. 1, 1914. Any discussion offered thereafter should preferably be in the form of a new paper.

Cyanidation of Silver Sulphide at Ocampo, Mexico

BY ROBERT LINTON, LOS ANGELES, CAL.

(New York Meeting, February, 1914)

THE Sierra Consolidated Mines Co., organized in 1909, owns, together with other holdings, practically all of the productive mineral area in the Ocampo district. Lying within this area are 15 mines, large and small, that had previously been worked and appear to have yielded, since the discovery of the camp, about 100 years ago, bullion of a total value of over \$50,000,000. The deepest mine, the Santa Juliana, had been worked to 1,100 ft. below the outcrop. The reopening of the mines involved, first, extensive and thorough development to open up the known ore-shoots at greater depth and explore the ledges for additional shoots, and, second, a revision of existing equipment and methods, so as to increase output and reduce cost of production. This paper will give some account of the metallurgical treatment and a description of the new mill to be built at El Salto.

The Ore

The ore is practically all argentite, Ag_2S , with some associated gold, and carried in a siliceous gangue. The typical ledge matter is an andesitic breccia cemented with quartz, or quartz stockwork in andesite.¹ The proportion by weight of silver to gold averages about 60 to 1. The silver sulphides occur ordinarily in rather fine dissemination, sometimes not being easily discernible with the naked eye, even in ores of very good grade. The ledges also contain considerable pyrites, which as a rule is barren. "Bronce" is the local term applied to such barren pyrites, and "Pasta" to such as carries values.

¹ The geology of the Ocampo district is described in the *Engineering and Mining Journal*, vol. xciv, No. 14, p. 653 (Oct. 5, 1912).

Analyses of ores from three of the principal mines are as follows:

	Per cent.	Per cent.	Per cent.
Insoluble.....	82.50	82.15	83.80
Fe.....	3.70	5.05	2.47
CaO.....	4.75	3.55	4.50
MgO.....	3.27	3.75	1.42
S.....	0.22	0.50	0.20
Al ₂ O ₃	1.61	2.34	2.13
MnO ₂	0.55	0.28	0.31
Cu.....	0.01	Nil	Nil
As.....	Nil	Trace	Nil
Sb.....	Trace	Nil	Nil
Loss in ignition.....	2.41	2.00	4.20
	99.02	99.62	99.03
Ounces Ag.....	16.55	88.30	11.10
Ounces Au.....	0.25	1.08	0.36
Acidity of ore (terms NaOH).....	0.20	0.39	0.25

The proportions of the metallic constituents of the ore are better shown by the analyses of concentrates and concentration tailings, as follows:

	Concentrates per cent.	Tailings per cent.
Insoluble.....	31.40	86.30
Fe.....	32.00	2.80
CaO.....	2.40	3.40
MgO.....	0.60	0.80
S.....	17.90	0.36
Al ₂ O ₃	0.70	1.78
MnO ₂	0.47	0.57
Cu.....	1.10	Nil
As.....	0.28	Trace
Sb.....	Trace	Nil
Ounces Ag.....	1376.00	11.20
Ounces Au.....	23.40	0.15

Recasting the analysis of the concentrates, the mineralogical composition would be about as follows:

	Per cent.
Iron pyrites.....	30.2
Chalcopyrite.....	3.0
Arsenopyrite.....	0.7
Argentite.....	5.4
Total sulphides.....	39.8
Oxides and silicates.....	49.0
Carbonates.....	5.4
Metallics.....	5.8
	100.0

Previous Milling Practice

Six mills had been operated in connection with the mines now owned by the company—the Guadalupe, Santa Juliana, Belen, San Ramon, Rosario, and El Salto. The San Ramon used Bryan mills for crushing, all of the others light stamps, the total capacity aggregating 90 stamps. All of these mills but the one at El Salto had been out of operation for some time, and had been dismantled.

Until about seven years ago, the treatment followed was plate-amalgamation, or more frequently pan-amalgamation, followed by concentration on Wilfley tables and vanners, with pan-amalgamation of the concentrates. Records of these milling operations are very incomplete, and probably not very reliable as regards the extraction obtained. A general idea of the results may be gained from the following extracts from these records:

Mill	Extraction		Bullion Fineness	Milling Costs Per Ton
	Au Per cent.	Ag Per cent.		
Santa Juliana.....	62	55	946	\$4.09
San Ramon.....	79	64	981	....
Belen.....	64	46	991	5.01
Rosario.....	73	51	971	3.25

The above extraction figures are based on the assays of heads and tailings. The actual recovery made in these old pan-amalgamation mills probably did not average over 60 per cent. of the gold and 50 per cent. of the silver in the ore.

The first cyanide plant in Ocampo was installed in 1906 at the pan-amalgamation mill at El Salto. The equipment consisted of one Farrel and one Sturtevant rock breaker; twenty 850-lb. stamps with Challenge feeders; three Wilfley tables; two sands-collecting tanks 15 ft. in diameter by 6 ft. deep, provided with Butters and Meins distributor; eight leaching tanks 15 ft. in diameter by 6 ft. deep; two slimes-collecting tanks 15 ft. in diameter by 6 ft. deep with cone bottoms; five Pachuca agitating tanks 12 ft. in diameter by 20 ft. deep; clarifying filter press; solution storage tanks and sumps; zinc-boxes, drier and melting furnace; small air compressor for agitating the Pachuca tanks; steam pumps for circulating water and solutions; grinding pan and settler for treatment of concentrates.

In this mill the battery pulp was run over Wilfley tables and the coarse sulphides were concentrated out, to be then treated by grinding in strong cyanide solution in one of the old amalgamating pans. The sands were drained as dry as possible in the collecting tanks and transferred to the leaching tanks in a small car; the thickened slimes (about 2.5:1) flowed directly to the Pachucas. The sands treatment appears to have

required about 20 to 25 days and the slimes treatment 8 to 10 days of which about 30 to 35 hr. was actual agitation in strong solution, the remainder being taken up with decantation and washing. According to such records as are available the average recovery at this mill was about 70 per cent. for both gold and silver, and the cyanide consumption per ton of ore more than 5 lb., a considerable portion of which was lost in waste solutions. Milling costs averaged about \$5 per ton.

Recent Operation

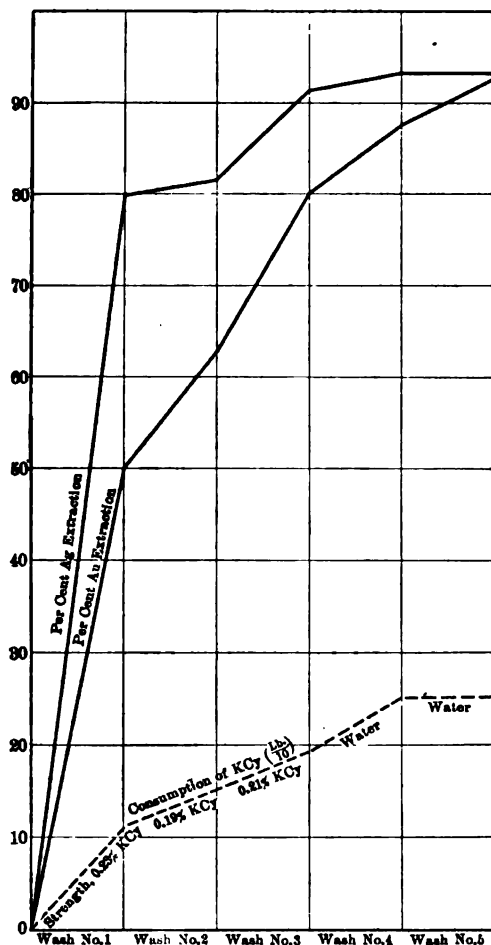
On account of the worn-out condition and inefficient arrangement and equipment of this cyanide mill, no attempt was made by the new company to operate it regularly; but it was utilized with advantage in test runs to determine the details of treatment that would yield the best commercial returns, considering extraction, cost, and time required. The ore milled, being only what was produced in the course of development work, amounted to 4,700 tons, from which bullion worth \$45,273.86, U. S. currency, was produced.

As the Pachuca tanks operated in parallel, it was easy to vary the treatment on individual charges of slimes, as well as sands, and in this way improved results were soon obtained. The time of treatment of the sands was reduced to 18 days, concentration was eliminated, a *spitzlütte* was placed ahead of the Butters distributor, the proper strength of solution was determined and the percentage of extraction was materially raised. Careful records were kept of the individual charges under special treatment and the results were plotted graphically. One of these curves is shown in Fig. 1, which shows the extraction of gold and silver and the consumption of cyanide and lime in connection with a charge of 20 tons of slimes. The results shown by the curves are metallurgical and do not take into account the additional losses, both of values and materials, that occur mechanically.

The operation of the mill showed conclusively that leaching should be eliminated. Where the treatment of the individual slimes charge was considered separately, and compared with the sands charge under treatment for the same length of time, the latter would contain at least three times as much gold and four times as much silver as the slimes residues. In the slimes charge shown in Fig. 1, 80 per cent. of the silver was dissolved in the first agitation with strong solution, lasting 20 hr., while the total extraction of silver in the sands rarely reached 75 per cent. at the end of 18 days.

Special Investigations

A large number of laboratory tests were carried on at the same time, concerning questions of sizing, chemical conditions influencing treatment, and tests on slimes charges of from 25 to 50 lb.



Total time agitated, 35 hr.
 Total time settling, 144 hr.
 Heads assay: Au, 0.08 oz.; Ag, 11.62 oz.
 Au extraction, 92.5 per cent.
 Ag extraction, 93.3 per cent.
 Total KCy consumption, 2.5 lb. per ton slime.

FIG. 1.—CURVE SHOWING RESULTS ON A CHARGE OF 20 TONS OF DRY SLIME.

Sizing

A number of sizing tests were made and the various products assayed. The screen assay of a characteristic sample of battery pulp, crushed to pass a 26-mesh screen, was as follows:

	Proportion of Total Weight	Assay per Ton		Contents	
		Au	Ag	Au	Ag
	Per cent.	Oz.	Oz.	Oz.	Oz.
On 40 mesh.....	4.0	0.16	7.8	0.006	0.31
Through 40 on 50.....	10.0	0.12	7.9	0.012	0.79
Through 50 on 60.....	4.3	0.12	8.9	0.005	0.38
Through 60 on 70.....	12.5	0.12	9.7	0.015	1.21
Through 70 on 90.....	9.0	0.12	9.9	0.010	0.89
Through 90 on 100.....	12.0	0.12	12.1	0.014	1.45
Through 100 on 120.....	4.7	0.12	4.11	0.005	0.66
Through 120 on 150.....	5.0	0.16	14.8	0.008	0.74
Through 150 on 200.....	19.5	0.16	17.5	0.031	3.41
Through 200 mesh.....	19.0	0.16	18.8	0.030	3.57
Combined sample.....	100.0	0.15	13.2	0.136	13.41

It will be noted that the gold is rather evenly distributed throughout all the sizes, but that there is a gradual increase in silver values in passing from the coarse to the fine sizes. Fine grinding is therefore necessary to expose the silver sufficiently to the dissolving action of the cyanide solution. The sizing tests indicate that the more nearly the ore is ground to pass 200-mesh, the better will be the extraction obtained.

Chemical Conditions Influencing Treatment

The elements unfavorable to cyanide treatment, such as copper, arsenic, antimony and sulphur, if present at all in this ore, occur in such small quantities as to exert practically no influence on the treatment. As to the manganese, the silver values do not appear to be in any case combined with it to form a refractory manganiferous silver ore, such as is somewhat frequent in Mexico.²

The water from the Jesus Maria arroyo, on which the mill is situated, was found to contain 77 parts solids per 100,000, the constituents of the solids being as follows:

¹ Experiments on such an ore are described in a paper by the writer published in the *Journal of the Chemical, Metallurgical and Mining Society of South Africa*, vol. ix, No. 3, p. 74 (Sept., 1908).

	Parts
SiO ₂	10.8
Fe ₂ O ₃ , Al ₂ O ₃	6.8
CaO.....	41.4
MgO.....	Trace
SO ₃	8.0
Cl.....	8.0
Organic and volatile.....	2.0
Total.....	77.0

Experiments on cyanide consumption by the arroyo water showed that after six hours' contact a quantity of cyanide had been consumed equivalent to 0.44 lb. KCy per ton of water, which was reduced to 0.11 lb. KCy per ton of water when alkali was added. A branch of the main arroyo flowing into it at the mill carries pure water, which did not attack the cyanide. The tests were made when the stream was at a low stage and the water naturally carried more impurities than would be the case during the greater part of the year.

The supply of lime heretofore available is quite impure, but contains nothing prejudicial to cyaniding. The analysis of an average sample of burned lime is as follows:

	Per cent.
SiO ₂	8.8
CaO.....	54.8
MgO.....	4.5
Fe ₂ O ₃	1.9
Al ₂ O ₃	3.2
CO ₂	13.9
H ₂ O.....	12.2
Total.....	99.3

Of this lime, 50 lb. digested for 6 hr. with a ton of standard KCy solution showed no cyanide consumption; hence the material could be used. After considerable search, however, a better grade of lime has been found, which can be obtained at a slightly higher cost.

Recasting the analysis of an average sample of battery heads for one month, and the analysis of the lime, water, and cyanide used, we find the chemical composition of the consolidated mill charge, as given below. In this month 40 lb. of lime was used per ton of ore; the ratio of solution to ore was 6 : 1; the strength of solution, 0.23 per cent., 120 parts of sodium cyanide being used to 100 of ore. The solids in the charge per ton of ore milled would be made up approximately as follows:

	Pounds		Pounds
Insoluble.....	1,755.29	CN.....	14.63
Fe.....	55.00	As.....	0.10
Fe ₂ O ₃	1.00	CO ₂	77.70
Fe ₃ O ₄		S.....	33.60
Al ₂ O ₃	24.87	SO ₃	0.08
CaO.....	114.41	Cl.....	0.08
MgO.....	0.80	Au.....	0.025
Cu.....	0.20	Ag.....	1.44
MnO ₂	10.00	Volatile }	0.09
Na.....	12.97	Organic }	

Special Tests on Small Samples

A model Pachuca tank 10 in. in diameter by 30 in. high and connected with small zinc-boxes was rigged up for experimental work. From 25- to 50-lb. samples were treated in this, and the details of treatment were worked out here and subsequently checked by agitation of 20-ton charges in the cyanide plant. The ore was ground to 120-, 150-, and 200-mesh; solutions of different strengths were used; and the various conditions influencing the treatment were thoroughly tested. Without going into the numerous details, the results may be summarized as follows:

It was not possible to obtain nearly as high extraction with pulp ground to 120- or 150-mesh as with that ground to 200-mesh—demonstrating the necessity of fine grinding.

The strength of solution most favorable for the treatment of this ore is about 0.32 per cent. KCy. Weaker solutions can be used to obtain equally high extraction if the time of treatment be increased. With this strength of solution the period of agitation necessary for extraction percentage as given below was 34 hr.

Protective alkalinity should be maintained during agitation up to 0.08.

The use of lead acetate was found to be of no benefit in connection with the treatment.

With the treatment as outlined above, the consumption of cyanide averaged about 1.4 lb. and that of lime about 12 lb. per ton of ore treated. These are the actual amounts of materials destroyed by the reactions of the process. Including mechanical losses, there would probably be in a working plant a consumption of about 2.5 lb. of 98 per cent. potassium cyanide, and 15 to 20 lb. of lime per ton of ore treated.

The extraction of silver from samples ground to 200-mesh varied from 84 to 89 per cent.; the gold extraction from 93 to 95 per cent. A recovery of 85 per cent. should be effected in operating.

Cyaniding Concentrates

A series of tests was also made on cyaniding the concentrates. The writer has already given details of these in a previous paper.¹ The results indicated that the most economical treatment was to grind the concentrates in 0.2 per cent. KCy solution, and agitate in a 0.6 KCy per cent. solution which was raised to 0.8 per cent. toward the end of the treatment, the protective alkalinity being maintained at 0.10. The use of lead acetate did not benefit the extraction; but a small amount assisted in keeping the solutions clear. In treating ore of ordinary grade, there is no benefit to be derived from concentrating. It may be of advantage in handling the rich ore from bonanza shoots such as appear to be characteristic of the ore occurrence here, having been encountered from time to time in the past. In the new mill, concentrating equipment is not provided, but the mill is so designed that this can be added when needed.

The New Mill

After the metallurgical details had been worked out a new cyanide mill was designed, which follows closely the outline of treatment derived from this preliminary work. The site selected was El Salto, where the old cyanide mill was located, since it is the most favorable as regards both the contour of the ground, and transportation of ore from the mines. The machinery for the first unit of this mill was ordered and construction work had been begun when it was decided to suspend operations until political conditions in Mexico should become more settled. The equipment for this first unit consists of the following:

One 20- by 10-in. Armour cast-steel Blake Marsden type rock breaker.

One battery of ten 1500-lb. stamps, with open-front mortars, fluted cam shaft, Blanton cams, individual El Oro guides, Nelson suspended automatic feeders.

One Newago screen.

Two 4 by 20 tube mills, roller bearing on discharge end, trunnion bearing on feed end, connected by single reduction gear to special type I 24 General Electric high-torque motors.

One Esperanza type classifier, 20 ft. 7 in. by 4 ft. by 3 ft. 8 in. maximum depth.

One 40- by 16-ft. Dorr thickener, with tank.

One 35- by 12-ft. Dorr thickener, with tank.

Three standard 15- by 45-ft. Pachuca agitators.

One 10- by 12-ft. tank with mechanical agitator.

One Oliver continuous alime filter, 125 tons capacity per 24 hr.

One Gwynne solution multistage centrifugal volute turbine pump, capacity 250 gal. per minute against 150 ft. head.

¹ *Journal of the Chemical, Metallurgical and Mining Society of South Africa*, vol. xiii, No. 1, p. 14 (July, 1912).

Two 4-in. Gwynne centrifugal slime pumps.

One 10- by 12-ft. slime receiving tank.

One 35- by 16-ft. main solution tank.

Two 16- by 10-ft. pregnant solution tanks with clarifying sand filters.

Two 20- by 14-ft. sump tanks.

Two double-column zinc-boxes.

One 5- by 5- by 6-ft. clean-up tank.

One S. H. Johnson precipitate press.

One tilting furnace of the Butters type, for No. 400 crucible.

One Hampton zinc lathe.

The rock breaker, stamp mill, and tube mills are manufactured by the English firm of Fraser and Chalmers.

The compressor to furnish air for the Pachuca agitators, and some other minor items, will be furnished from equipment previously on hand.

Outline of Treatment

The ore from the mines is received in a small bin above the rock breaker, and crushed in the latter to 2-in. size. It is then delivered by a belt conveyor to a Newago screen above the battery ore bins which constitute the main storage. Material coarser than $\frac{3}{8}$ in. goes to the battery bins and the fines go to a separate bin at one end. The fines are delivered by a belt conveyor directly to the classifier. The over-size is crushed in the battery to 5-mesh and passes to the classifier. The classifier is set between the two tube mills and receives the tube-mill discharge as well as the battery pulp, constituting a closed circuit with constant overflow of slimes. It is estimated that the ratio of solution to ore in the tube-mill feed will be 6 to 1.

The overflowing slime is pumped to the primary thickener, where it is thickened to a 2 to 1 consistency, the overflowing solution being returned directly to the battery. The thickened pulp flows to the Pachuca agitators, which are connected in series for continuous agitation. Cyanide is dissolved in a small tank above the agitators, and added to the slime as required to maintain the solution at proper strength. At the estimated capacity of the mill the pulp would require 55 hr. to make the circuit of the tanks. The surplus agitator capacity is to provide against loss of values by a portion of the slime passing from one tank to the next before it is thoroughly agitated, and to prevent cutting down the capacity of the mill when a tank has to be put out of service temporarily, as for instance through accumulation of slime on the bottom. The arrangement is such that any tank can be thrown out of the circuit and the slime by-passed.

From the Pachucas the slime passes to the secondary thickener, where the ratio of solution to dry slime is reduced to 1.5 to 1. It then passes to

the mechanical agitator, and barren solution of the lowest grade available is added and the whole thoroughly agitated, effecting a preliminary washing and dilution. It is then filtered in the Oliver filter and the residues are washed and discharged. It is estimated that these residues will carry 30 per cent. solution, to make up for which and for evaporation will probably permit the use of a quantity of wash water equivalent to 60 to 70 per cent. of the tonnage of ore milled.

The overflowing solution from the secondary thickener and the solution from the Oliver filter flow to the clarifying sand filters, thence to the zinc-boxes and barren-solution sumps. The barren solution is pumped to the mill-solution tank above the battery.

The designing of the mill and selection of equipment has kept in view the larger capacity that will probably be required ultimately. Units of the same capacity as this first one can be added as rapidly as needed without any interruption in operating at the existing capacity.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the New York meeting, February, 1914, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Apr. 1, 1914. Any discussion offered thereafter should preferably be in the form of a new paper.

Notes on Conservation of Lake Superior Iron Ores¹

BY C. K. LEITH, MADISON, WIS.

(New York Meeting, February, 1914)

THE questions as to what grades of ore it pays to conserve for the future, and the valuation of low-grade reserves, are becoming immediate and definite as applied to individual ore deposits, and seem to call for some sort of quantitative answer. Both opinion and practice involving these questions differ widely. The number of variables in this problem is so large that final solution will perhaps never be agreed upon, yet there seem to me to be certain controlling factors which can be placed in quantitative relation and serve to reduce the number of variables which it is necessary to consider in a given instance.

I assume that it will not pay either for the individual or for the State to conserve any ore when the present cost of conservation (by stock piling or otherwise), when compounded at 6 per cent. interest for the number of years which would elapse before this ore is used, will exceed the profit which the ore will yield when it is used. It may be urged that any loss to the individual may be made up in gain to the State. This might be true if there was any definite limit to the amount of iron ore, but when we remember that iron makes up 4 per cent. of all the rocks of the earth and the amount of rock carrying iron in excess of 20 per cent. is, for practical purposes, unlimited, it is apparent that posterity is assured of its iron ore. The changes will be mainly in methods and cost of extracting the ore. Therefore, any expenditure of money or effort now, which when compounded will exceed the worth of the effort or money needed in the future to utilize the iron, is a net loss both to the individual and to the community.

On the accompanying plate, Fig. 1, prepared by W. J. Mead, the amount of any given sum compounded at 6 per cent. interest for a given

¹The subject of the economic possibilities of conservation is approached by the economists from a point of view which is perhaps new to some mining men. The reader may be interested in two short general papers on the subject, entitled:

Some Economic Aspects of Conservation, by Ralph Henry Hess, *Original Communications to the Eighth International Congress of Applied Chemistry*, vol. xxvi, p. 711 (1912).

The Economic Possibilities of Conservation, by L. C. Grey, *Quarterly Journal of Economics*, vol. xii (May, 1913).

period up to 40 years may be read. For instance, if it cost 10c. a ton to conserve ore, at the end of 20 years this amount will be 32c.

The present cost can be easily determined. Both the time at which an ore will be used and the future profit are matters of speculation, but I believe it is possible to set certain limits for them.

Future Profits.—Just as ores now show the widest variety of availability, depending on chemical and mineralogical composition, texture, geologic and geographic position, cost of mining, etc., so the ores of lower grade which will be used in the future will show like variation in availability. The only factor common to all ores which can be used to summarize and compare the different ores is profit per ton. Profit determines whether a given ore can now be used and will determine this in the future. If, therefore, we can approximate the profit per ton for any given ore, at any given time in the future, we can easily calculate how much, if anything, one can afford to spend now to save this ore. This profit can never be accurately predicted in advance, but I believe it may have much the same relation to values of higher-grade ores as it has at present. If a 50 per cent. ore now shows a mining profit of \$1.50 per ton, the lower grades as calculated from penalties will show profits of a fraction of this amount, ranging down to zero. In certain favored Lake Superior localities 38 to 40 per cent. low-phosphorus, high-silica ore can be mined now at a profit of 25c. or less. In less favored localities, where now only the higher-grade ores are being mined, the time will come when the lower-grade ores will necessarily be mined; but when this time arrives, the profit per ton will probably be at least as low as the present profit for such low-grade ores mined from the most-favored localities and as low as the price we now figure from penalties, for the tonnage of the lower-grade ore available is so vast and so widely distributed that its extraction will be necessarily accomplished on a small margin of profit, like a manufacturing enterprise, such as, for instance, the utilization of clay and cement materials. The total cost to the consumer may be the same, but relatively more of the cost will go to fuel and to handling the larger quantities of material necessary to produce a given unit of finished product.

More specifically, I cannot see that there is any basis for hope that 40 per cent. Mesabi ores will be mined at any more profit per ton than the Marquette low-grade ores. When these 40 per cent. Mesabi ores come to be mined they will be in competition with enormous quantities of 40 per cent. ores elsewhere, and they will be mined at a very low margin.

Time.—For any given iron-ore district, the rate of exhaustion of the higher-grade reserves may be roughly figured and the time estimated in which the successively lower grades are likely to come into use. For instance, the average percentage of iron in the Lake Superior ores has been showing during the past decade a drop of about a third of 1 per cent. per year. With a present average of about 49 per cent. natural, at the present

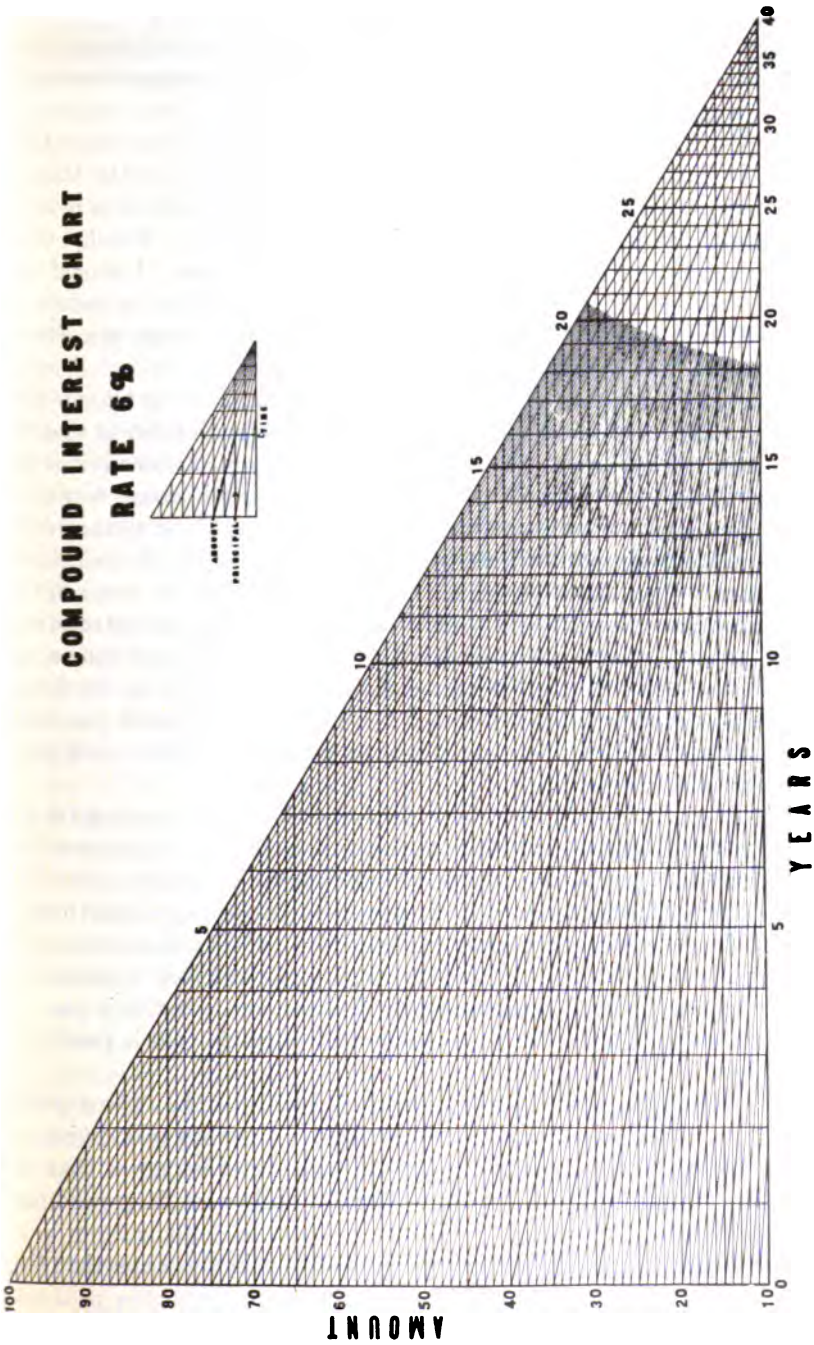


Fig. 1.—CHART FOR DETERMINING COMPOUND INTEREST AT 6 PER CENT. FOR ANY PERIOD BETWEEN 1 AND 40 YEARS.

rate of decrease of grade a 45 per cent. ore would come to be used in about 12 years. This time, of course, would not be uniform for all districts. Certain ores will be used long before others. This is a minimum time, because we must remember that as the grade falls the tonnage of available ores is enormously larger, which will slow up the rate of the decrease of grade. Also it is to be remembered that really only a small portion of Lake Superior is thoroughly explored. I suspect that, outside of the Mesabi, for a hundred years to come high-grade reserves will be added to more or less in proportion to the expenditure made in exploration. Finally, there is the probability of effective competition of foreign ores. I should say, roughly, that in any given district, one would need to be optimistic to predict the use of an average grade 5 per cent. lower than the present prevailing grade in a period shorter than 30 years.

Interpretation of Chart.—With these facts in mind, let us assume that it costs now 25c. per ton to conserve an ore which is 5 points lower than the present commercial grade. Let us also take an optimistic view of the situation and say that this lower grade when mined is going to yield a profit of 50c. a ton, which is certainly better than anything that could be figured out from the present profits on such ores, or from the calculation of penalties. It is apparent from the chart that such an ore must be used in 12 years unless there is to be a loss on the money invested in conserving the ore. If, on the other hand, it costs only 10c. per ton to conserve this ore, and the profit is assumed to be 50c. per ton in the future, it would be possible to hold the ore 28 years. If the profit per ton is assumed to be 25c. and the present cost of conserving it is 5c., it is possible to hold it for 28 years.

Without going into further illustrations, and without arguing for any specific figures of time and profit, it seems clear that there is a narrow limit to the sums which it is wise to spend to conserve low-grade ores. It is my opinion that 25c. per ton profit at a period over 30 years away may be the condition of mining the greater part of the ores 5 points lower than the present standard for any locality. It is apparent that it would pay to spend a very few cents a ton to conserve these ores. If this is true, the present value per ton in the ground of such low-grade ores is practically negligible.

In the above discussion royalty is included as a profit. The payment of royalty to the fee owner by the lease holder amounts to a division of profit. The profit of either party would, therefore, be lower than the figures I have given. It follows that royalties on low-grade ore will need to be pretty low.

The above suggestions are offered tentatively in the hope that they may bring out some discussion.

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The American Steel-Rail Situation

BY ROBERT W. HUNT, CHICAGO, ILL.

(New York Meeting, February, 1914)

ONE of the most serious and important economic administrative problems facing American railway authorities to-day is that of their rails, and it is one to which much thought is being given, not only by the executive officers of the railways and the manufacturers of the steel rails, but also by State and National commissions. It is realized by many and admitted by some that the present situation is one which cannot continue. The roadways of railways must be made more secure, or the weight of rolling stock and the speed of trains must be lessened; and the desired result must be attained with the minimum outlay of money, both in expenditure on plant and in cost of operation. If the investment per mile is too large, or through the lessening of tonnage and efficiency of equipment the cost of operation is too great, the desired and demanded cheap service cannot be rendered to the public. Therefore, the weight of equipment cannot be greatly reduced, and lessening the rapidity of service would be far from satisfactory; consequently, the safety of the roadway must be secured with the least practical outlay.

It is imperative that the roadbed should be properly graded, with the fewest practically possible curves; that it should have good ballast, be well drained, have good ties properly spaced, and be laid with sound rails of suitable weight, efficiently joined together, and that the whole property be carefully and intelligently cared for.

My province is to treat of the sound rails.

During the last few years there has been renewed interest in and discussion of that question, and I know that many rail makers not only have been and are desirous of maintaining the highest standards of manufacture which they may have attained, but have been and are seeking to better their product, in several instances devoting much time and money to that end. At the same time, they realize that the cost of any improvement in quality which they may accomplish must be kept within certain commercial bounds; and that fact is as fully understood by their patrons as by themselves, and it should be kept in mind by all who discuss the question.

As a matter of record, I present in Fig. 1 a summarized statement of

what may be called the mechanical practice of the steel-rail mills of the United States and Canada.

It will be noted that the several works differ in their practice as to kind of steel, size of heats, size of ingots, kind of blooming and rail trains, number of passes in the rolls of both trains, and as to direct rolling into rails; also as to the details of the finishing departments of the several mills. In consequence of such variations, there are, of course, differences in the operating practice of the several plants. One thing that, in my judgment, has had a great effect upon the quality of the product of all the mills is that the workmen have been and are paid on a tonnage or piece basis, with, in some cases, an additional prospective bonus based on quantity of product. Unfortunately, after the produced rails had left the works, there was but little chance of the identity or individuality of the workmen in the different departments of the works, who made them, being connected with them. It is true that a number corresponding with that of the heat of steel from which they had been rolled, and the month and year in which they were made, and the name of the works, were branded on each rail, but to actually identify the steel maker who made the steel, the heater who heated it, the roller who rolled it, the shearman who cropped the blooms, etc., would have been a complicated and practically impossible proposition. One result was that if, for any reason, such as delays from accidents to machinery, etc., the quantity of product was threatened, there was temptation to in some way cut corners, the workmen knowing that if the rails were once out of the mill they need not worry over any individual responsibility, which feeling was simply human.

In an endeavor to meet this and other phases of the situation, some two years ago I ventured the establishment of a system of more constant and thorough inspection of rail making than had been generally, if at all, practised. In this movement I received the support at first of several and later of many of the railroad companies of this continent, and I am happy to say that I have also received the loyal support of the officials of the several steel companies. This system of inspection I explained in a former paper, presented at the Cleveland meeting, October, 1912.¹

I have repeatedly shown that without sound ingots there will not be any certainty of producing sound rails; and that, as each ingot is an individual steel casting, some means should be adopted of testing for soundness the rails produced from each ingot; and until reliable ways of casting sound ingots are adopted the importance of such testing should not be overlooked or underestimated. It is possible to make sound ingots. It will cost more than the present practices; but is that a good argument against it? Whether that increased cost should be added to the selling

¹ Recent Developments in the Inspection of Steel Rails, *Bulletin* No. 72, Dec., 1912, pp. 1487 to 1495.

price of rails is a commercial question outside of the province of this paper. The increased cost of individual ingot testing is so small that it should not be a matter of much commercial importance.

There is another feature of the situation which demands and is receiving serious consideration from railway officers, consulting engineers, the steel works officials, and others. That is, the desirability, if not the absolute necessity, of increasing the weight of rail sections. A number of such sections have been designed, and some have been rolled, and the rails are in use; but there is a metallurgical feature involved which should not be overlooked.

The experience of many railways has been that their earlier rails, which were of lighter sections, gave better service than the later heavier ones, and the track men will tell you that when they cut one of the old rails they found a close, fine-grained structure, while the larger rails show a more or less coarse one. The old lighter rails permitted the fining effects of the rolling to penetrate, and, the mass of metal in their heads being comparatively small, the effect of the interior contained heat passed off sooner. The foregoing conditions result in the webs and flanges of all rails having a finer structure than their heads; therefore, as we increase the size of the rail sections we will certainly decrease their proportionate strength, and under present manufacturing conditions the heavier rails will have less resistance to the abrasive wear of the traffic. Nevertheless, there seems to be a necessity for heavier rails, and so much the better, if we can also make them proportionately stronger.

Excepting in the ability to roll rails by the use of fewer passes in the rolls, and to handle the operations mechanically and automatically, there have not been any radical changes in rail rolling. The plan of rolling reductions has remained much the same. Some experiments have been made, and various schemes have been proposed, but none of them are in active use. In my judgment, the present situation demands serious consideration, even though it should require very radical changes in the rolling machinery of the existing rail mills. If we must have rails with more metal in their heads, as well as thicker webs and flanges, it is most important that the work of reduction and formation from the, say, 8- by 8-in. section of the blooms shall be applied in a way to penetrate and fine the metal in the rail heads. I shall not here attempt to particularize the way, but no doubt a modification of the universal mill, *vide* the Gray mill for structural sections, will suggest itself as one possible way, and I know of several schemes which contemplate putting work on the top of the heads in addition to only the sides, as is the case with the present mills. If that must be accomplished to solve the problem, it can and will be done.

Once more I emphasize the truth that the physical treatment of the metal is of at least equal importance with its chemical composition.

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Notes on Some Heating and Cooling Curves of Professor Carpenter's Electrolytic Iron

BY ALBERT SAUVEUR, CAMBRIDGE, MASS.

(New York Meeting, February, 1914)

In an important paper on The Critical Ranges of Pure Iron¹ presented at the May, 1913, meeting of the Iron and Steel Institute, Professor Carpenter reports and illustrates the results obtained by him in determining the critical points of some very pure electrolytic iron sheet about 0.01 in. thick. The iron strip was rolled into the form of a cylinder 1½ in. long and ½ in. wide, weighing 42 g., the thermo-couple being inserted in a small hole in the center. The points Ac3 and Ar3 were readily detected, as well as the point Ar2, but the point Ac2 was absent from every heating curve. The author concluded from this occurrence that the conception of A2 as an independent allotropic change must be abandoned.

At the October, 1913, meeting of the American Institute of Mining Engineers, Dr. G. K. Burgess and J. J. Crowe read a paper on The Critical Ranges A2 and A3 of Pure Iron² in which they described some extremely important experiments conducted by them at the Bureau of Standards, Washington, D. C. They tested Professor Carpenter's electrolytic iron and detected a sharp and well-defined absorption of heat corresponding to the point Ac2. Professor Carpenter's failure to detect this point is explained by them on the ground that unless the iron be in a single piece entirely surrounding and in contact with the thermo-couple junction, the thermo-couple will integrate the irregular progress of the heat through the sample and the curves will lose their sharpness. In discussing Messrs. Burgess and Crowe's paper, Professor Carpenter accepted this explanation as probably accounting for the absence of Ac2 in his heating curves.

Professor Carpenter had the kindness to supply me with some of his electrolytic iron. Heating and cooling curves of this metal were taken in the metallographic laboratory of Harvard University by F. C. Langenberg by means of an electrically heated tube furnace and a Le Chatelier-Saladin self-recording thermo-electric pyrometer, as constructed by Pelin, of Paris. The electrolytic sheet was tightly hammered around the

¹ *Journal of the Iron and Steel Institute*, vol. lxxxviii (1913, I), pp. 315 to 326.

² *Bulletin* No. 82, October, 1913, pp. 2537 to 2591.

thermo-couple. These curves are shown in Figs. 1 and 2. The sharp occurrence of the point Ac2 at 765° C. should be noted.

In view of the recent and extraordinary attempt of Professor Benedicks³ to account for the presence of the Ac2 point in Dr. Burgess's samples of electrolytic iron on the ground that the latter used an alternating current for heating his furnace, it should be noted that a *direct* current was used in obtaining the curves reproduced here.

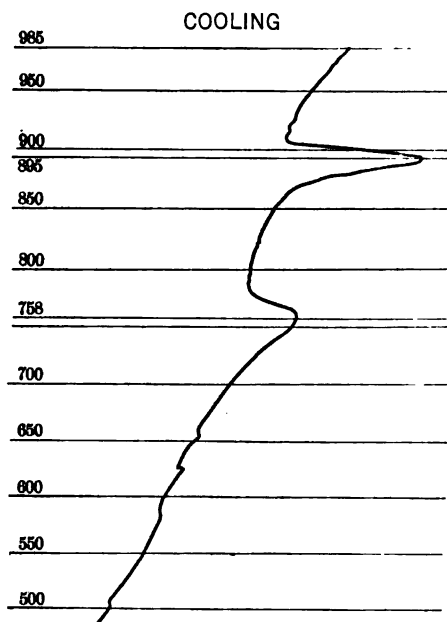


FIG. 1.—COOLING CURVE OF PROFESSOR CARPENTER'S ELECTROLYTIC IRON.

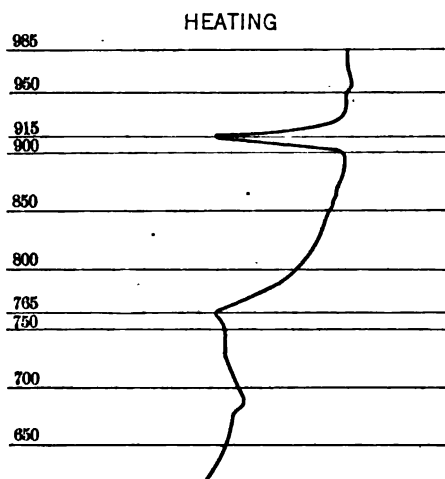


FIG. 2.—HEATING CURVE OF PROFESSOR CARPENTER'S ELECTROLYTIC IRON.

Scientific speculation is not only permissible, but highly commendable and fruitful, provided it rests on a substantial foundation of experimental facts. Scientific speculations, on the contrary, however brilliant as intellectual gymnastics, if they lack such support are merely destructive, and when indulged in by investigators of repute, their ill-founded views are likely to be accepted by others but partly informed or biased, and the progress of science be retarded.

The existence of A2 in pure iron as an independent point is no longer a debatable question. Whether this point is or is not an allotropic point appears to depend upon our conception of allotropy. If it be insisted that an allotropic point necessarily implies a crystallographic change, or, in other words, that polymorphy and allotropy are synonymous, then it may be claimed, with reason, that A2 is not an allotropic point, since crystallo-

³ *Bulletin* No. 84, Dec., 1913, p. 2877.

graphic differences between beta and alpha iron have never been discovered. On the contrary, if, more rationally in my opinion, we believe that an abrupt heat evolution on cooling and a corresponding heat absorption on heating, when occurring in a pure element without change of state, must be taken as an evidence of allotropy, then A2 must be an allotropic point. Are not such thermal disturbances due to spontaneous changes of internal energy necessarily caused by molecular changes; *i.e.*, in the absence of change of state, by allotropic changes? We are strengthened in our belief in the allotropic character of the A2 point by the discontinuity in many of the physical properties of iron occurring at that point. It has been contended by those who doubt the allotropy of A2 that the absence of any expansion at the Ar2 point and of contraction at Ac2 argues strongly against allotropic change. Messrs. Burgess and Crowe, in the paper already mentioned, discuss this point as follows:

"Both from the work of Charpy and Grenet and of Broniewski, observations on the expansion of iron give no indication of the existence of A2. The former place the contraction observed as lying in the interval from 860° to 890° for iron with 0.03 carbon, while the latter finds it above 950° for electrolytic iron.

"This disagreement here is great enough to again raise the question, as was done by Le Chatelier in 1899, of the speed and other conditions of heating, and also whether the sensibility of the methods used was great enough to detect A2. Even its non-existence, in so far as expansion is concerned, would prove only that iron immediately above and below A2 has the same coefficient of expansion, or simply that the A2 transformation is unaccompanied by appreciable change in volume, a not unreasonable possibility. The more recent experiments of Rosenhain and Humfrey would appear to indicate a slight volume change accompanying A2." It should also be recalled that Osmond took exception to Messrs. Charpy and Grenet's conclusions drawn from their own experiments as to the absence of dilatation at Ar2. Osmond claimed that the curves obtained by Charpy and Grenet do indicate a dilatation at Ar2, the authors failing to notice it because the transformations not being sudden, the expansion likewise is gradual, whereas they were looking for sudden dilatations only.



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Manganese-Steel Rails

BY SIR ROBERT HADFIELD,* F.R.S., LONDON, ENGLAND

(New York Meeting, February, 1914)

SINCE the writer has been intimately connected with the development of manganese steel for many years, some remarks upon the early work with regard to the rolling and forging of this material might be of interest, and particularly as to the question of rails of special quality and of superior wearing qualities.

In a paper on Iron Alloys, with Special Reference to Manganese Steel, read before this Institute at the International Engineering Congress in Chicago in 1893,¹ the writer mentioned that, about 20 years ago, his firm in Sheffield produced railroad material, such as tires and axles, of forged and rolled manganese steel, thus showing that this product could be manipulated and worked up into the various required forms. The tires



Manganese Steel.

Ordinary Carbon Steel.

11 g. removed from manganese-steel rail by drilling in 20 min., as compared with 750 g. from an ordinary carbon-steel rail in the same time.

FIG. 1.—MANGANESE-STEEL RAIL OF $7\frac{1}{2}$ KG. PER METER ROLLED IN FRANCE IN 1904.

illustrated in the paper referred to above formed a particularly difficult class of work to produce in a special steel, but no special obstacles were met with. Although there was no difficulty at that time in making and producing manganese steel in various forms, forged, rolled or pressed; nevertheless, on account of its higher expense, sufficient encouragement

* Honorary member.

¹ *Trans.*, xxiii, 148 (1893).

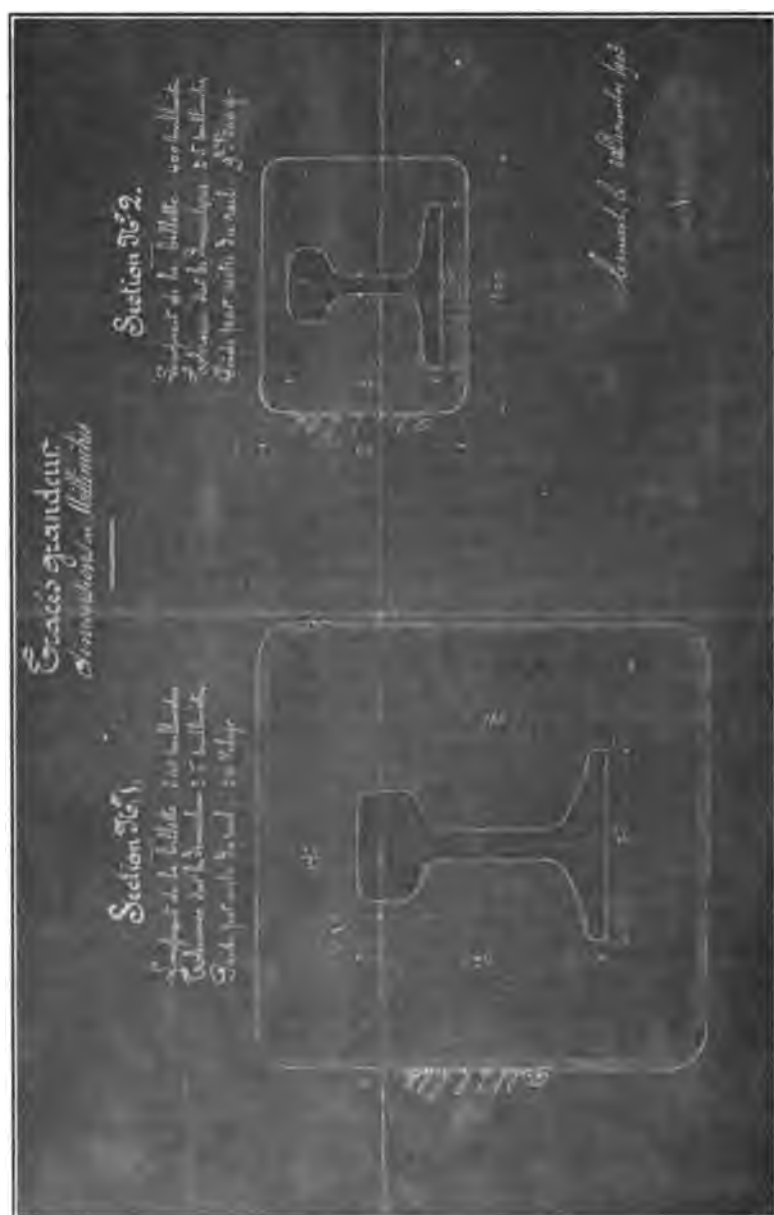


FIG. 2.—PHOTOGRAPH OF ORIGINAL TRACING PREPARED FOR THE PRODUCTION OF THE RAIL SHOWN IN FIG. 1.

was not then obtained from the users to introduce these products on a large scale. There never has been any real difficulty in obtaining forged, rolled, or pressed manganese steel, provided the consumer was willing to pay the necessarily higher cost as compared with ordinary steel.

The matter was further pursued in the present decade: In 1904, a French manufacturer produced rolled manganese-steel rails of $7\frac{1}{2}$ kg. per



FIG. 3.—SPECIMEN OF STEEL FROM WHICH RAIL SHOWN IN FIG. 1 WAS ROLLED.
BENT DOUBLE COLD. TENACITY, 60 TONS PER SQUARE INCH.
ELONGATION, 40 PER CENT.

meter, as shown in Fig. 1. The original tracing prepared by this manufacturer on Dec. 30, 1903, showing the sizes of the billets and rails to be produced, is reproduced in Fig. 2. These rails were rolled without any incident. One of them was experimented upon by the writer in the following manner: After drilling for 20 min., 11 g. of manganese steel were removed; while, in the same time, 750 g. were removed from an ordinary carbon-steel rail. The results of this test are shown in the photographic view, Fig. 1. A piece of this same manganese steel bent

double cold, as shown in Fig 3 The material showed a tenacity of 60 tons per square inch, with an elongation of 40 per cent.

This test was so satisfactory that manganese-steel rails of heavy section, 100 lb. per yard, varying from 6 to 12 m. in length, were then produced in the same rolling mill. A section of one of these rails is shown in Fig. 4.

A large number of these rails were rolled in 1907, and were supplied to the Metropolitan Electric railway of Paris (in the commencing of operations on which, it will be remembered, there was some delay), and put to work, among other places, at the Bastille station in that city. These

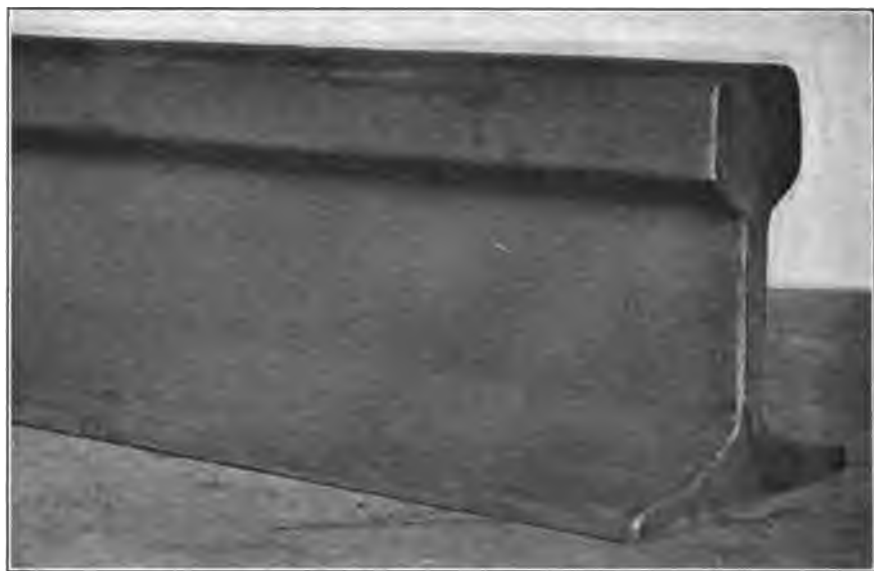


FIG. 4.—MANGANESE-STEEL RAIL, 100-LB. SECTION, TAKEN FROM A LOT OF 50 TONS ROLLED IN 1907 FOR METROPOLITAN ELECTRIC RAILWAY, PARIS, FRANCE.

rails, after several years of service on severe curve work, have given great satisfaction. After three years' hard service, the actual wear was found to be not more than about $2\frac{1}{2}$ mm. It has been estimated that the rails will remain in service for six to seven years before being worn out, whereas ordinary steel rails wear out and have to be replaced in less than a year. The rails in position are shown in Fig. 5.

A plant for producing sound ingots under the system devised by the writer was described in a paper² presented to the Institute at the February, 1913, meeting This system, as adapted to the manufacture of manganese-steel ingots, is illustrated in Figs. 6, 7, and 8. No less than 90 per

² *Trans.*, xlv, 473 (1913).



FIG. 5.—MANGANESE-STEEL RAILS, 100-LB. SECTION, ABOUT 40 FT. LONG, IN PLACE AT BASTILLE STATION, PARIS, FRANCE.



FIG. 6.—MANGANESE-STEEL INGOTS.

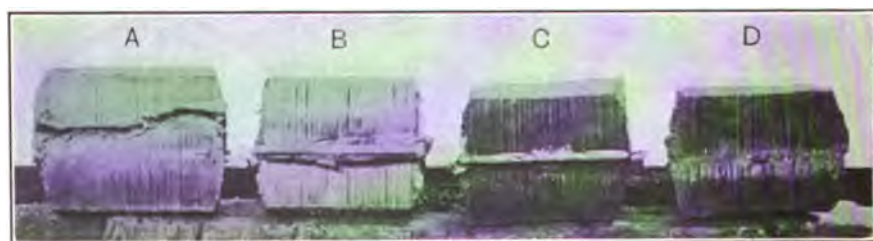


FIG. 7.—HEADS FROM ABOVE INGOTS PARTLY COGGED AND THEN CUT OFF.

cent. of sound material is obtained from an alloy steel, which will therefore be seen to offer great advantages. Each 1 per cent. of expensive material saved means that much reduction in the cost of production.

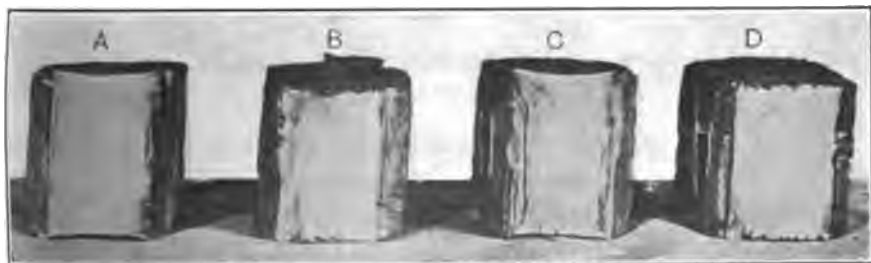


FIG. 8.—FRACTURES FROM THE UPPER END OF TOP BILLET FROM EACH OF THE INGOTS SHOW IN FIG. 6.

The consumer has now to pay for 15, 20, or even 30 per cent. of waste in special steels made in the ordinary way, whereas this waste can to a large extent be avoided. Moreover, better and more uniform quality of alloy steel can be obtained.

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Scientific Installations for the Economical Burning of Liquid Fuel of any Specific Gravity.

BY WILLIAM NEWTON BEST,* NEW YORK, N. Y.

(New York Meeting, February, 1914)

OIL burners, oil furnaces, and methods of installation, have been the subject of many articles, but information concerning oil-burning systems, based upon scientific principles, is still in great demand, especially in the manufacturing districts of our country.

Fuel oil, as it is termed (this being the residuum from oil refineries), has for many years been of great service to our manufacturers, and has justified its popularity not only by producing a superior manufactured product, but by turning out approximately 50 per cent. more product than can be made with coal fuel under like conditions. To install a system requiring only an oil-storage tank, a small pump, and an oil-supply main with numerous laterals leading to the various burners, furnaces, boilers, etc., is a comparatively simple matter; and, because fuel oil is very volatile, it is not necessary to heat it, even during the winter months in a very cold climate. Furthermore, only a small amount of power is required to atomize fuel oil, this often being done by a positive pressure blower, or by a mechanical burner. An analysis of fuel oil, together with that of various other liquid fuels, is given in Table I.

TABLE I.—*Analyses of Liquid Fuels*

	Fuel oil	California asphaltum base crude oil	Mexican (Tampico Field) crude oil
Carbon, per cent.....	84.35	81.52	83.83
Hydrogen, per cent.....	11.33	11.01	12.19
Oxygen, per cent.....	2.82	.....	0.43
Nitrogen, per cent.....	0.60	6.92	1.72
Sulphur, per cent.....	0.90	0.55	2.83
Gravity, degrees Baumé.....	26 to 28	12 to 36	12 to 23.8
Weight, pounds per gallon.....	7.3	7.6	7.82
Calorific value, B.t.u. per lb.....	18,350 to 19,348	18,462 to 18,980	18,493
Vaporizing point, degrees F.....	130	230	175

* Vice-Chairman, Committee on Petroleum and Gas.

In the middle and eastern sections of the United States, four systems for burning fuel oil have been successfully employed: namely, gravity feed; column gravity feed; the pneumatic system; and oil-pump feed.

Gravity Feed.—In the gravity-feed system, the oil is supplied to the burner from a supply tank located approximately 8 ft. higher than the burners. This is the cheapest and most simple system to install and operate, but is not approved by the National Board of Fire Underwriters.

Column Gravity Feed.—By column gravity feed, the oil is pumped from the storage tank through the supply pipes to the burners. The excess oil is then forced into a column, consisting of a pipe 2 in. in diameter and approximately 20 ft. in height, provided at the top with a vent and an overflow pipe, which carries the excess oil which overflows back to the oil-storage tank. It is obvious that by this method, the pressure maintained at any burner depends upon the difference in level between the burner and the top of the oil column. When this difference in level is 16 ft., the corresponding pressure would be approximately $7\frac{1}{2}$ lb.

The Pneumatic System.—In the pneumatic system, the compressed-air line of the factory is connected to the top of the oil-storage tank, thus putting the oil under a pressure, which may be regulated and controlled by means of an adjustable set-screw on the pressure-reducing valve on the compressed-air line. The pipe which supplies oil to the shop is coupled at or near the bottom of the oil-storage tank.

Oil-Pump Feed.—The pumping system is now most commonly used. Here a pump is employed to force the fuel from the storage tank and deliver it through a main supply pipe and laterals leading from it to the different burners. A pressure-relief valve, located at or near the pump, maintains the required oil pressure, as well as allowing the excess oil to return through an overflow pipe to the storage tank. In this system, the oil-storage tank is provided with a filling pipe, usually 3 in. in diameter; a man-hole; and a vent for the escape of gas. The regulations of the National Board of Fire Underwriters in the central and eastern parts of this country, require the tank, or tanks, to be located at least 30 ft. from any building, and to be covered with 2 ft. of earth. The type of oil pump is sometimes reciprocating, operated either by compressed air or by steam, and sometimes rotary or triplex, driven either by motor or by belt.

The Use of Oils Heavier than Fuel Oils.—The advent and popularity of automobiles and oil engines has created such a demand for by-products of fuel oil that it has now become too valuable to be used as fuel, notwithstanding its excellent quality. The manufacturing world must, therefore, install in future some system by which heavier oils can be used, and especially petroleums from the Mexican and Southern California fields, which are particularly available as fuel, because they contain so small a proportion of volatile oil, gasoline, kerosene, etc. Analyses

of Californian and Mexican crude oils are given in Table I. The completion of the Panama Canal will, no doubt, result in vast quantities of this fuel being delivered to the southern and Atlantic ports of the United States.

Efforts have been made in the eastern parts of the United States during the past year and a half, to burn the heavy petroleum from the Mexican fields, which has an average gravity of 14° Baumé. Through ignorance, when attempting to use this oil, no means were provided for heating the fuel in the storage tank; the oil pump which had been used for ordinary fuel was not changed to adapt it for a heavier fuel; the oil pipe lines were not laid so that the fuel would be constantly in circulation; and the pressure valve was not located appropriately for the heavier oil. The result was that the fuel system had to be shut down until the oil had been removed from the tanks by buckets.

I have often been amused by the efforts of persons who were accustomed to burn fuel oil, but who were not familiar with the use of heavy crude oils. For, notwithstanding that the heavy crude oil, when appropriately handled, is a better fuel than ordinary so-called fuel oil, because it has a higher calorific value per gallon, nevertheless, these efforts have often resulted in crude oil being condemned.

Oil-Burning Systems.—The system shown in Fig. 1, by the use of which any petroleum from 12° to 46° Baumé can be scientifically used as a fuel, comprises: an oil-storage tank provided with a 5-in. filling pipe, a $\frac{3}{4}$ -in. steam coil, a man-hole, a vent pipe, an overflow pipe, a suction-pipe flange, etc., as required by the National Board of Fire Underwriters; an oil pump of adequate proportions operated by steam or compressed air, or, if it be a triplex pump, driven by a belt or motor; and an oil-supply pipe so located that it follows the line of furnaces, boilers, kilns or other equipment, without the use of laterals, and with riser pipes from oil-supply pipe to burners, each of which must not exceed 3 ft. in length. The system must also include an appropriately located pressure-relief valve, and, adjacent to it, a by-pass valve to drain the oil-supply pipes when the system is not in service. An overflow pipe is connected with the relief valve and also with the by-pass valve, so that the excess oil will be led back to the storage tank. This system insures a constant, perfect circulation of the oil to each burner, and eliminates all dead ends on the supply lines.

Coating the oil-pipe threads with a paste consisting of litharge and glycerine before assembling, will prevent leakage. The unions should be ground joint. Gum or rubber should never be used, and lead gaskets should be used in flanges. I deem it always advisable to use malleable-iron beaded fittings on all oil-pipe lines.

Heating the Oil.—The object of heating the crude oil is to reduce its viscosity, and it should be heated in the storage tank to a temperature

that will allow it to be pumped easily. The oil is also heated in the supply and overflow pipes by running a steam pipe alongside of them, and inclosing both in an 8-in. square box which, when the pipes have been tested, is filled with dry sand. By regulating the amount of steam passing through the heater pipe, the oil is supplied to the burners at a temperature just below its vaporizing point. When the pipes are inclosed in the manner described only a small quantity of steam is needed, and, by laying the steam pipe below the oil pipe in the box, it is accessible at all times. Some persons prefer to heat the oil by passing a 3/8-in. steam pipe through the oil-supply pipe. The first cost of this is cheaper, but, if the steam pipe should leak, it is difficult to make the necessary repairs.

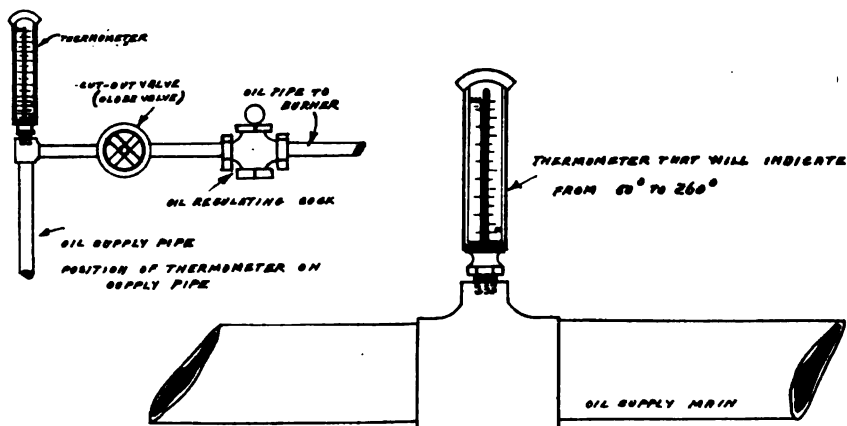


FIG. 2.—POSITION OF THERMOMETERS ON OIL-SUPPLY MAIN.

Accurate Temperature Required.—The economic advantage of accurately heating the oil to the desired temperature is shown by some tests in which a saving of 20 per cent. of Mexican crude oil required was made by heating it to 160° F. (which is 10° below its vaporizing point) instead of 120° F. The control of temperature is so important that thermometers should be used in direct contact with the fuel as it passes to the burner (see Fig. 2). Two or three such thermometers, well located, will save much oil and increase the output of the furnaces. The overheating of the oil is an example of carelessness which should be severely condemned, and which may readily be detected by the puffing of the burner, due to escaping vapor.

Liability to Fire through the Use of Oil.—There is less liability of fire from liquid fuel, employed by means of a modern fuel-supply system, than there is from the use of coal or coke, yet there are many different rules prevailing in different parts of the country for the location of oil-storage tanks. In the eastern and middle sections of our country, the

law of the National Board of Fire Underwriters require all storage tanks to be placed 30 ft. from any building and covered by 2 ft. of earth, while in San Francisco they are placed in the space formerly used for coal, immediately under the sidewalk, and are filled by oil-tank wagons or oil-tank cars from the street.¹ I have at hand evidence which proves that, of the hundreds of oil-storage tanks located in the city of San Francisco at the time of the late earthquake and disastrous fire, not one exploded or increased the conflagration or was the direct cause of financial loss. It is impossible for many manufacturers to place oil-storage tanks 30 ft. from any building, because their buildings cover their entire ground, and the Fire Underwriters' law quoted forbids them to be placed under the

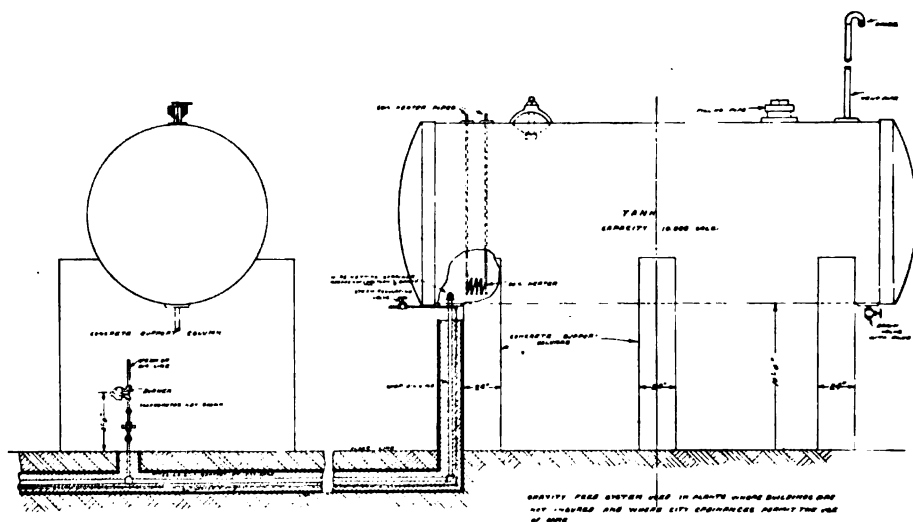


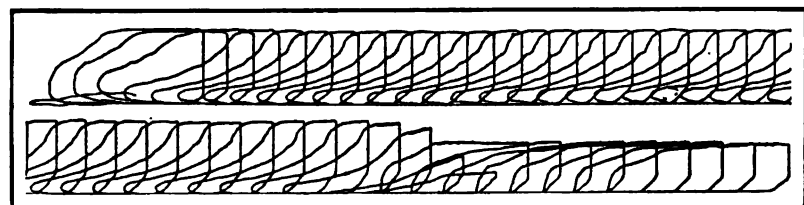
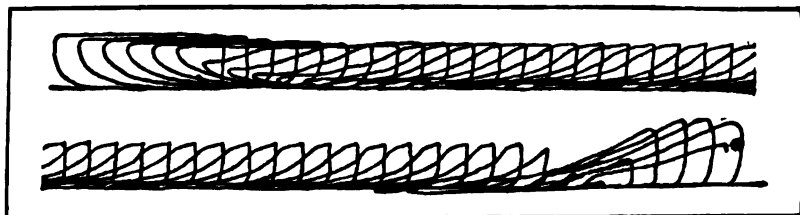
FIG. 3.—GRAVITY-FEED OIL-BURNING SYSTEM.

sidewalks. This places some manufacturers at an unfair disadvantage in competition with others, because it prohibits them from the use of crude fuel for such purposes as the heat treatment of metals, drop forging, welding, etc.

All manufacturers are to-day looking for quantity as well as quality of output, and, as oil can be safely stored under the street sidewalk in one section of the country, then, why can it not in another section? In other words, why should we not have uniform laws? If crude oil were as volatile as gasoline, there might be some grounds for fear, but it is not. As far as the danger from dripping oil is concerned, it may be obviated

¹ Resolution of Executive Committee adopted Aug. 20, 1901, by Board of Fire Underwriters of the Pacific. Circular No. 185.

Two Hoist Diagrams



The top sketch is a continuous indicator card recording one full trip of a 32x72 in. first motion Corliss Hoist—depth, 1800 ft., load, 5.15 tons.*

The lower sketch is a similar card, recording one trip of a Sullivan Geared Automatic Slide Valve Hoist, size, 16x18 in., depth, 269 ft., load, 5 tons.

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* See Bulletin A. I. M. E., Sept., 1913

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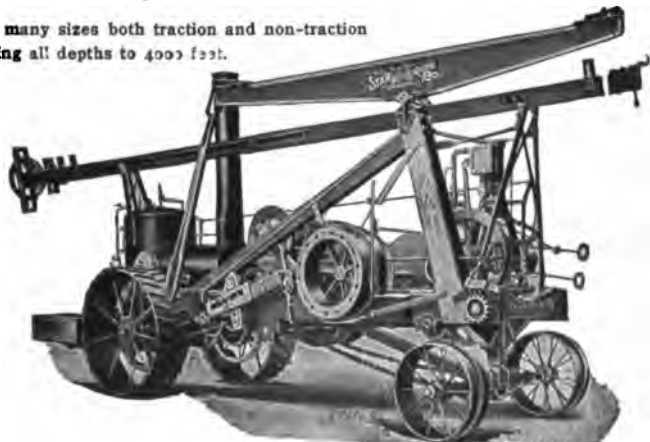
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706 pages, 6 by 9 inches.

Bound in cloth, \$5.00

Bound in half-morocco, \$6.00

VOLUMES XXXVI to XL—1905 to 1909

186 pages, 6 by 9 inches.

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Taken together these two indexes furnish in convenient form for ready reference everything of importance contained in the *Transactions*, and give to both member and non-member, whether possessing a set of the *Transactions* or not, the means of ascertaining at a minimum expenditure of time and trouble the exact contents of the volumes on any given subject of special interest.

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PROPOSALS FOR MEMBERSHIP. A blank proposal for membership is included in each Year Book and Bulletin. In the event of not being able to secure such a one, applications for membership can be made out on any blank piece of paper, provided they include the class to which the candidate is proposed, whether member, associate or junior member; the signature of three members or associates (junior members must also have the endorsement of two of their instructors); a brief history of the candidate, including date and place of birth, his education and technical record, and finally a signed statement by the applicant that he desires to become a member.



MARCH, 1914



Bulletin of the American Institute of Mining Engineers

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Our New Members

In view of the large increase in the number elected to membership in the Institute during 1913, the question might be raised, "Has the standard of membership been maintained?"

Reference to the list of 439 men who have accepted election in 1913 will show that 181 have had 10 years', or more, experience in the practice of the profession, 64 of these having had over 20 years' experience, and 32 having had over 30 years' experience. Further, 265 of the new members are graduate engineers and 49 are under-graduates in mining schools and have been elected to Junior membership.

Thus, it is seen that our new members bring to us ripe experience and exact knowledge that should result in mutual benefit.

Very respectfully,

Committee on Increase of Membership,

ADOLPHE E. BORIE, *Chairman.*

THOMAS T. READ, *Secretary.*

29 West 39th Street, New York, N. Y.

PROPOSAL FOR MEMBERSHIP

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(Name in Full)

Occupation _____

Address _____

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Members or
Associates.**

*Place of birth*_____ *Year of birth*_____

*Education, general and technical, when, where and how acquired,
with degrees, if any.*

Dates

[illegible]

ARTICLE II MEMBERS

Institute shall comprise four classes

SEC. 2. The following classes of persons shall be eligible for membership in the Institute, namely : as

As Junior Members, all students in good standing in engineering schools who have not taken their degrees and who are nominated by at least two of their instructors. * * *

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BULLETIN OF THE AMERICAN INSTITUTE OF MINING ENGINEERS

No. 87

MARCH

1914

Published Monthly by the American Institute of Mining Engineers at 212-218 York St., York, Pa., H. A. WISOTZKEY, Publication Manager. Editorial Office, 29 West 39th St., New York, N. Y., BRADLEY SROUGHTON, Editor, F. O. PIERCE, Asst. Editor. Cable address, "Aime," Western Union Telegraph Code. Subscription (including postage), \$10 per annum; to members of the Institute, public libraries, educational institutions and technical societies, \$5 per annum. Single copies (including postage), \$1 each; to members of the Institute, public libraries, etc., 50 cents each.

Entered as Second Class matter January 28, 1914, at the Post Office at
York, Pennsylvania, under the Act of March 3, 1879.

SALT LAKE CITY MEETING

The One Hundred and Eighth Meeting of the Institute,
for the presentation and discussion of technical papers, will
be held at Salt Lake City, Utah, August 10 to 14, 1914.

**ALL PAPERS TO BE PRESENTED AT THIS MEET-
ING MUST BE IN THE HANDS OF THE SECRETARY
ON OR BEFORE MAY 31, 1914.**

BOARD OF DIRECTORS

Meeting of Feb. 17, 1914.—President Thayer announced the appointment of the Membership Committee, consisting of Karl Eilers, Chairman; W. R. Ingalls, J. D. Irving, J. H. Janeway, Jr., and Sidney J. Jennings.

Volume X of the *Transactions* was ordered to be reproduced by the anastatic process.

Upon recommendation of the Executive Committee it was resolved that inasmuch as the total indebtedness of the Institute an account of the Land obligation is about \$34,000, a check for about \$28,000, together with the individual promises of certain members aggregating about \$6,000, be accepted from Dr. James Douglas as fulfillment of his undertaking to discharge the debt.

Three Associate Members, 119 Members and 20 Junior Members were elected to membership in their respective classes. The status of two Associate Members was changed to that of Member.

Twenty-one members who had paid all arrears of dues were reinstated to membership.

The resignations of 10 members were accepted.

Karl Eilers was elected a Vice-President of the Institute to fill the unexpired term of Benjamin B. Thayer, who had been elected President.

Sidney J. Jennings was elected First Vice-President of the Institute.

George C. Stone was elected Treasurer of the Institute.

Rossiter W. Raymond was appointed Secretary Emeritus of the Institute.

Bradley Stoughton was elected Secretary of the Institute.

The Executive Committee, consisting of Benjamin B. Thayer, James F. Kemp, Charles F. Rand, Joseph W. Richards, and Albert R. Ledoux, was elected.

The Finance Committee, comprising Charles F. Rand, Karl Eilers, and W. L. Saunders, was elected.

At the request of 30 members residing in the Pennsylvania anthracite district, the Pennsylvania Anthracite Local Section was established.

Chicago Local Section.—A meeting of members of the Institute residing in and near Chicago, at which the Secretary of the Institute was present, was held at the La Salle Hotel, Chicago, on Feb. 24, to discuss the feasibility of establishing a Local Section in Chicago. As a result of the discussion, a petition for the organization of a Local Section, signed by the members present, was sent to the Institute office. The following Committee on Organization has been appointed: H. W. Nichols, Chairman; J. A. Ede, E. C. Reeder, G. M. Davidson, F. K. Copeland, and G. W. Gennet, Jr.

ANNUAL MEETING OF THE INSTITUTE

The One Hundred and Seventh meeting of the Institute, which was also the Annual Meeting, was held in New York City on Feb. 16 to 19, 1914. The social features were in charge of the New York Local Section of the Institute. The program of the meeting had been distributed to all members in advance and was carried out substantially as announced. The total registration was 391 members and guests.

About 70 papers were presented, and more than 50 of these were actively discussed. The technical sessions were animated and interesting, and not only the Board of Directors, but the members at large, are deeply appreciative of the successful efforts of the various Technical Committees, but especially the Iron and Steel Committee, the Committee on Petroleum and Gas, the Committee on Mining Law, the Committee on the Use of Electricity in Mines, and the Committee on Mining Geology.

The social functions were enjoyed by all persons present, and were carried out without a hitch or an unpleasant detail. Very much praise and gratitude has been expressed for the able and generous efforts of the various Committees, to all of which sincere thanks are extended, and especially to the Executive Committee of the New York Section.

SCHOOL OF MINES, COLUMBIA UNIVERSITY

The School of Mines of Columbia University will celebrate the fiftieth anniversary of its foundation on May 28 and 29, 1914. The program will be as follows:

Thursday, May 28. Evening: Reception in the Gymnasium.

Friday, May 29. Morning: Formal registration, distribution of badges, etc.

11 A.M.: Formal academic exercises in Gymnasium, at which addresses will be delivered by distinguished engineers from abroad and this country, and honorary degrees will be conferred upon certain distinguished graduates.

Noon: Luncheon in the Commons.

Afternoon: Meeting of the various sections of engineering activity—Mining and Metallurgy, Civil Engineering, Mechanical and Electrical Engineering, Chemistry.

Evening: Banquet at the Waldorf-Astoria.

PERSONAL

(Members are urged to send in for this column any notes of interest concerning themselves or their fellow-members.)

Members and guests who registered at Institute headquarters during February:

Paul S. King, Wilmington, Del.
 A. Del Mar, South Pasadena, Cal.
 T. D. Babbitt, Nampa, Idaho.
 H. L. Williams, Newtonville, Mass.
 F. W. Bacorn, Pittsburg, Pa.
 Huntington Adams, Mexico, D. F.
 Clifton B. Johnson, New York, N. Y.
 W. Spencer Hutchinson, Boston, Mass.
 F. Louis Grammer, Leesburg, Va.
 H. C. H. Carpenter, London, England.

William Kelly, Vulcan, Mich.
 F. H. Armstrong, Vulcan, Mich.
 Reginald E. Hore, Toronto, Canada.
 Tom M. Owen, Broken Hill, Australia.
 Percy E. Barbour, Candor, N. C.
 Karl Nibecker, Youngstown, Ohio.
 G. A. Reinhardt, Youngstown, Ohio.
 Herbert B. Cox, Boston, Mass.
 E. C. Pechin, Buchanan, Va.

William H. Hulick, of New York, was elected President and Treasurer of the Warren Foundry & Machine Co., at the annual meeting of stockholders on Feb. 9, at Phillipsburg, N. J. Mr. Hulick has been a director since 1889 and has served as Vice-President and Assistant Treasurer since 1890.

Edward B. Durham, Dept. of Mining, University of California, will conduct a course in petroleum mining and chemistry.

Eli T. Conner has located his office at Room 1315, Stephen Girard Bldg., Philadelphia, Pa.

Herbert L. Williams has accepted a position with the New Jersey Zinc Co., with headquarters in New York.

J. V. W. Reynders, of the Pennsylvania Steel Co., was elected Vice-President of the Bridge Builders' Society at its recent annual meeting.

H. C. Hoover will be in New York on March 4, and will be presented with the medal of the Mining and Metallurgical Society of America before he sails for London on March 11.

Dorsey A. Lyon has been appointed Chairman of the Committee on Electrometallurgy of Iron and Steel of the American Electrochemical Society.

R. B. Brinsmade spent a fortnight in February studying the mineral possibilities of Central Jalisco.

William Fleet Robertson has been appointed Provincial Assayer for British Columbia to fill the vacancy caused by the resignation of Herbert Carmichael.

Carl J. Trauerman, of the metallurgical firm of Rothwell & Trauerman, Butte, Mont., will have charge of the milling operations of the Bully Boy Co., Marysvale, Utah, after March 1.

W. H. Henderson Scott has left for Central America in connection with business for Messrs. Breitung & Co.

T. Skewes Saunders, Superintendent of Mines for the Teziutlan Copper Co., Puebla, Mexico, expects to spend the summer in England visiting various mining districts.

Irving R. Gard has severed his connection with the Canadian Collieries (Dunsmuir), Ltd., of Victoria, B. C., to accept the management of the Mecca Colliery Co. His headquarters will be at Eagle, W. Va.

John M. Sherrerd has been made Secretary of the Stroh Steel Hardening Process Co., House Building, Pittsburg, Pa.

POSITIONS VACANT

(Under this heading will be published notes sent to the Secretary of the Institute by members or other persons.)

A copper company in Arizona desires a young engineer to assist the superintendent and take charge of the surveying, sampling and assaying. A graduate mining engineer with a few years' experience in mine surveying and sampling preferred. Salary, \$125 to start. No. 10.

A company in Quebec desires a metallurgist familiar with copper smelting to remodel an old plant and carry on experimental work to determine whether its ore can be smelted profitably in the district. No. 11.

A foundry making a specialty of medium and light weight steel castings of high grade wants a competent man as assistant manager capable of taking complete charge of production in the absence of the general manager. No. 12.

ENGINEERS AVAILABLE

(Under this heading will be published notes sent to the Secretary of the Institute by members or other persons.)

Member, technical graduate, aged 35, with 10 years' experience in mining, cyaniding, and copper lixiviation in Arizona, Colorado, Nevada, Mexico, and Central America, desires a position, preferably in Spanish American country. No. 50.

Member, 34, married, coal mine manager, experienced in pitching and faulted veins, coal washing, and coke burning, desires position, preferably in Alaska. A-1 references. No. 63.

Member, technical graduate, aged 35, with experience in the design and construction of concentrating, cyaniding, and smelting plants, desires position as chief engineer or chief draftsman. No. 64.

Technical graduate, aged 29 years, with mining, geological, and laboratory experience, desires position as engineer, assayer, or geologist. Speaks German and Spanish fluently. No. 65.

Member, graduate mining engineer, aged 30, with broad experience in mining and engineering practice, will be open for engagement about May 1, 1914, as superintendent or manager of mining or milling plant, or reporting work. At present engaged in private practice in Montana. No. 66.

Member, graduate mining engineer, aged 24, single, with two years' experience as steam power plant superintendent, and two years in geological and mining work in coal, iron, and copper fields, desires position on geological staff or as engineer and geologist with small company. At present underground construction foreman with large copper company. No. 67.

Member, technical graduate, 28 years old, married, with four and one-half years' experience as book-keeper, assayer, surveyor, and assistant superintendent, desires position with a good company. No. 68.

Member, technical graduate, 36 years old, married, 15 years' mining and smelting experience, with present employer 10 years, desires change. Prefers position as executive for mining or smelting company. No. 69.

Member, graduate mining engineer, 17 years' experience as mining engineer and mine manager, examinations, reports, litigation. Experience confined to gold, copper, and iron. Open for position with responsible persons or company. No. 70.

Mechanical engineer. Specialty, smelter construction. Has had entire charge of the mechanical and electrical field work during construction of several large smelters; also hydroelectric installations. No. 71.

Member, technical graduate, aged 35, with experience as assayer, chemist, and superintendent with copper mining and smelting companies, desires position as mine or mill superintendent. No. 72.

Technical graduate, aged 34, with experience in chemical and metallurgical research work, desires position in East as chemist and metallurgist. No. 73.

Member, technical graduate, aged 41, with 16 years' experience in Mexico and United States as assayer, chemist, ore buyer, mine superintendent, superintendent of lead smelter, and in metallurgical research work, desires position with copper or lead smelting and refining company. No. 74.

Graduate mining and metallurgical engineer with 23 years' experience, chiefly in charge of smelting and concentration works and as manager and engineer for both oxidized and sulphide copper properties and of lead and zinc sulphide mines, desires position as manager or consulting engineer for good mining or metallurgical company. No. 75.

IRON AND STEEL COMMITTEE

ALBERT SAUVEUR, *Chairman*

A. A. STEVENSON, *Vice-Chairman*

HERBERT M. BOYLSTON, <i>Secretary</i> , Abbot Bldg., Cambridge, Mass.	Robert W. Hunt,	E. Gybbon Spilsbury,
Guilliaem Aertsen,	J. E. Johnson, Jr.,	J. S. Unger,
John Birkinbine,	Charles Kirchhoff,	Felix A. Vogel,
William H. Blauvelt,	Richard Moldenke,	Leonard Waldo,
Charles A. Buck,	Charles F. Rand,	William R. Walker,
F. D. Carney,	Joseph W. Richards,	William R. Webster,
James Gayley,	C. F. W. Rys,	Frederick W. Wood.
Henry D. Hibbard,		
Henry M. Howe,		

Messrs. Guilliaem Aertsen, C. A. Buck, and F. D. Carney have accepted membership on the Committee.

At the Iron and Steel session of the February meeting 16 papers on iron and steel were read, and 12 of these were obtained through the efforts of the Iron and Steel Committee.

It was with the greatest difficulty that the papers for this meeting were preprinted on account of delays in receiving some of the manuscripts. On this account, discussions on the iron and steel papers read at the February meeting will be received up to April 8, 1914. They should be sent directly to the Secretary of the Institute. It is again urged that manuscripts for future papers be sent in at an early date.

It is planned to hold a meeting of the Institute next October and it is hoped that this can be held under the joint auspices of the Iron and Steel Committee, the Committee on Petroleum and Gas, and the Committee on Coal and Coke.

The following subjects have been selected as special topics for the October meeting:

Metallurgical Fuels.

Electric Furnaces.

Duplex Processes.

Papers for the October meeting must be in the hands of the Secretary of the Institute not later than August 10, and they should, therefore, be in the hands of this Committee not later than August 1.

HERBERT M. BOYLSTON, *Secretary*.

NEW YORK LOCAL SECTION

Executive Committee

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ARTHUR S. DWIGHT, *Vice-Chairman*

THOMAS T. READ, *Secretary*, Woolworth Bldg., New York, N. Y.

E. MALTBY SHIPP, *Treasurer*

GEORGE F. KUNZ

W. DE L. BENEDICT

Meeting, Jan. 16, 1914

A meeting of the New York Local Section of the American Institute of Mining Engineers was held at the Engineering Societies Building, 29 West 39th Street, New York City, Jan. 16, 1914, the Chairman, L. D. Huntoon, presiding. Forty members were present. In the absence of the Secretary, C. A. Bohn was appointed Secretary *pro tem*.

N. H. Darton, Geologist of the U. S. Geological Survey, delivered an address on The Occurrence of Gas in Coal, illustrated by lantern slides of charts, curves, and tables showing various features of gas occurrences. J. W. Richards, J. T. Beard, W. L. Saunders, L. D. Huntoon, and Mr. Darton participated in the discussion which followed the address.

THOMAS T. READ, *Secretary*.

MONTANA LOCAL SECTION

Executive Committee

E. P. MATHEWSON, *Chairman*

FRANK M. SMITH, *Vice-Chairman*

D. C. BARD, *Secretary*, Montana State School of Mines, Butte, Mont.

JAMES L. BRUCE

OSCAR ROHN

The annual meeting of the Montana Local Section of the American Institute of Mining Engineers was held at the Silver Bow Club, Butte, Mont., on Feb. 16, 1914, and was attended by 45 members and several guests. The Chairman, E. P. Mathewson, presided.

The officers of the Section were unanimously re-elected for the ensuing year.

Papers as follows were presented and discussed:

C. W. GOODALE: The Drumlummon Mine.

C. D. DEMOND: Economy and Efficiency of Reverberatory Smelting.

BANCROFT GORE: The Labor Crisis in Chile.

D. C. BARD, *Secretary*.

COLUMBIA LOCAL SECTION

*Executive Committee*F. A. THOMSON, *Chairman*GEORGE W. RODDEWIG, *Vice-Chairman*L. K. ARMSTRONG, *Secretary-Treasurer*,

P. O. Drawer 2154, Spokane, Wash.

R. S. McCaffery

S. H. RICHARDSON

The members of the Columbia Local Section of the American Institute of Mining Engineers were invited to participate in a joint meeting with the Spokane Sections of the American Institute of Electrical Engineers and the American Society of Civil Engineers, held at the University of Idaho, Moscow, Idaho, Jan. 17, 1914. There were present 252 members and guests. L. K. Armstrong, A. I. M. E., acted as Chairman of the meeting, and J. T. Percival, Jr., A. I. E. E., as Secretary. The following papers were read and discussed:

J. C. RALSTON, A. S. C. E., A. I. M. E.: Estimates on a Hydroelectric Plant for a Western City of 125,000 Inhabitants.

F. A. ROSS, A. I. M. E.: Surface Tension Flotation Concentration of Heavy Sulphides.

PROF. R. S. McCAFFERY, A. I. M. E.: Recent Experiments with the Electric Furnace for the Reduction of Lead and Zinc Ores.

J. B. FISKEN, A. I. E. E., Chairman of the Spokane Section, A. I. M. E.: The Little Falls Tie Line.

A quarterly meeting of the Columbia Local Section was held at the Spokane Hotel, Spokane, Wash., on Feb. 13, 1914. About 30 members and guests were in attendance. Papers as follows were read and discussed:

F. G. COTTRELL, U. S. Bureau of Mines: The Relation of the Bureau of Mines to the Mining Industry.

PROF. H. R. ROBBINS, Washington State College: The Utilization of the Iron Resources of the Pacific Northwest.

L. K. ARMSTRONG, *Secretary*.

BOSTON LOCAL SECTION

*Executive Committee*ROBERT H. RICHARDS, *Chairman*ALBERT SAUVEUR, *Vice-Chairman*AUGUSTUS H. EUSTIS, *Secretary-Treasurer*, 131 State St., Boston, Mass.

TIMOTHY W. SPRAGUE

HENRY A. WENTWORTH

Seventeenth Meeting

The seventeenth meeting of the Boston Local Section was held at the Engineers' Club, 2 Commonwealth Avenue, Boston, Monday evening Feb. 2, 1914. There were 18 members present.

Chairman Robert H. Richards presided at the dinner, after which Prof. H. O. Hofman delivered an address on Some Modern Aspects of the Metallurgy of Copper. Professor Hofman confined his remarks mainly to the treatment of sulphide ores.

AUGUSTUS H. EUSTIS, *Secretary*.

INTERNATIONAL ENGINEERING CONGRESS, 1915

The attention of all engineers is called to the International Engineering Congress to be held in San Francisco in 1915 in connection with the Panama-Pacific Exposition, under the auspices of the American Society of Civil Engineers, American Institute of Mining Engineers, American Society of Mechanical Engineers, American Institute of Electrical Engineers, and the Society of Naval Architects and Marine Engineers.

The sessions will be held in 11 sections and the proceedings will be published in 10 volumes of about 500 pages each, with a somewhat smaller volume containing all general proceedings and an index digest of all papers. The subdivision into sections, with titles of volumes of transactions, are shown in the adjacent form of application, which may be detached and forwarded with remittance as indicated.

All persons interested are invited to become members whether or not they may be able to attend the Congress.

The membership fee of \$5 will entitle holder to the volume of general proceedings and index digest and to any other single volume according to choice. Other volumes may be subscribed for according to a sliding scale depending upon the number of volumes taken.

The American Institute of Mining Engineers is an underwriter to the general guarantee fund for the necessary expenses of the Congress. Prompt action on the part of members in sending in their subscriptions to membership in the Congress will aid effectively in carrying on the necessary preliminary work without further present financial demands on the Institute for this purpose.

The Committee of Management of the Congress therefore specially requests all members of the Institute to respond promptly with their subscriptions.

APPLICATION FOR MEMBERSHIP

To be detached and mailed with remittance to W. A. Cattell, Secretary, Foxcroft Bldg., San Francisco, California, U. S. A.

The undersigned desires to enroll his name as a member of the International Engineering Congress, to be held in San Francisco, September 20-25, 1915.

Enclosed herewith you will find
(Check—Money Order—Draft)
for \$5.00 in payment of the Membership fee.

In addition to the general Index Volume, I select Volume No. as listed below, as the volume I am to receive for this fee.

INDICATION OF PROBABLE CHOICE OF OTHER VOLUMES:

☐ The Entire Set	☐ Vol. VI.. Mechanical Engineering
☐ Vol. I... The Panama Canal	☐ Vol. VII. Electrical and Mechanical Engineering
☐ Vol. II... Waterways and Irrigation	☐ Vol. VIII. Mining Engineering and Metallurgy
☐ Vol. III.. Municipal Engineering	☐ Vol. IX.. Naval Architecture & Marine Engineering
☐ Vol. IV.. Railways and Railway Engineering	☐ Vol. X... Military Engineering
☐ Vol. V... Materials of Engineering Construction	

I shall be especially interested in the volumes which I have marked thus: X, and while I do not subscribe for them nor commit myself in any way to do so at a future time, if ordering, they would probably constitute my selection.

Signature

Address

Member of

(Date) 191

LIBRARY

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

AMERICAN SOCIETY OF MECHANICAL ENGINEERS

AMERICAN INSTITUTE OF MINING ENGINEERS

UNITED ENGINEERING SOCIETY

WILLIAM P. CUTTER, Librarian

The Library of the above-named Societies is open from 9 A.M. to 10 P.M. on all week-days, except holidays, from September 1 to June 30, and from 9 A.M. to 6 P.M. during July and August. The Library contains about 55,000 volumes, including sets of technical periodicals and the publications of scientific and technical societies.

Members of the Institute, with few exceptions, are forced to spend a portion of their time in localities isolated from sources of information. To these the Library can render valuable service through correspondence; letters requesting information will receive special attention. The Library is prepared to furnish references and copies of articles on mining and metallurgical subjects; to determine the existence of mining-maps, and to furnish general information as to the geology and mineral resources of all countries.

All communications should be made as definite as possible so that the information received may be what is desired and not include collateral matter which may not be of interest. The time spent in searching for such collateral matter will be saved, and the information will be sent more promptly and in more usable shape.

The members of the Institute can be of service to the Library by forwarding copies of mining-reports, maps privately issued, and similar material, which will be classified, indexed, and made available to other members. Suggestions for additions to the Library, either by purchase or personal solicitation as gifts, will be welcomed. It is hoped that members while in the city will use the Library freely, and assurance is given that most careful service will be rendered to them.

LIBRARY ACCESSIONS

New Books on Mining, Metallurgy, and Chemistry

AUSTIN BROOK IRON-BEARING DISTRICT, NEW BRUNSWICK. Ottawa, 1912.
ELECTRIC FURNACE. Ed. 2. By Alfred Stansfield. New York, McGraw-Hill Book Co., 1914. Price \$4. (Gift of Publisher.)

[NOTE.—The first edition of Professor Stansfield's book was published in 1907, and the growth of the industry is well shown by the size of the second edition, which contains over twice the number of pages. The Librarian remembers vividly his work with another college senior, in 1888, attempting to manufacture sulphuric acid in an electrical furnace. This was soon after the Cowles process was invented.

Professor Stansfield's book commends itself to a bibliographer by the wealth of accurate footnote references, and to a reader by its index.—W. P. C.]

CHEMISER KALENDER, 1914. Vols. 1-2. By Rudolf Biedermann. Berlin, 1914.

GOLD DREDGING. By T. C. Earl. London, 1913.

HANDBUCH DER MINERALCHEMIE. Band III, pt. 2. By C. Doelter. Dresden, 1913.

LE HAUT FOURNEAU ELECTRIQUE. By M. Paul Nicou. Paris, 1913.

MINING LAWS OF THE UNITED STATES AND CALIFORNIA. (Bull. 66, California State Mining Bureau.) Sacramento, 1914.

PRELIMINARY CONCENTRATION TESTS ON MESABI ORES. (Bull. 2, Experiment Station, Minnesota School of Mines.) Minneapolis, 1913. (Gift of Minnesota School of Mines.)

TESTS OF PERMISSIBLE EXPLOSIVES. (Bull. 66, U. S. Bureau of Mines.) Washington, 1913.

New Books on Geology and Mineral Production

BIBLIOGRAPHY OF NORTH AMERICAN GEOLOGY FOR 1912, with subject index. (Bull. 545, U. S. Geol. Survey.) Washington, 1913.

BRITISH COLUMBIA BUREAU OF MINES. Preliminary Review and Estimate of Mineral Production, 1913. (Bull. 1.) Victoria, 1914. (Gift of British Columbia Bureau of Mines.)

CARTE GEOLOGIQUE INTERNATIONALE DE L'EUROPE. Part VIII. Berlin, 1913. GEOLOGIC RECONNAISSANCE OF THE CIRCLE QUADRANGLE, ALASKA. (Bull. 538, U. S. Geol. Survey.) Washington, 1913.

GEOLOGISCHES ZENTRALBLATT. Generalregister, Vols. 1-15. Leipzig, n. d. GEOLOGY OF THE TITANIUM AND APATITE DEPOSITS OF VIRGINIA. (Bull. 111-A, Va. Geol. Survey.) Charlottesville, 1913.

JAHRBUCH FÜR DAS BERG UND HUTTENWESEN IN KÖNIGREICH SACHSEN, 1913. Freiberg, 1913.

LIST OF THE MINERALS OF NEW ZEALAND. Wellington, 1913.

MINERAL RESOURCES OF ALASKA. Report on progress of investigations in 1912. (Bull. 542, U. S. Geol. Survey.) Washington, 1913.

MINERVA JAHRBUCH DER GELEHRTEN WELT. 1913-14. Strassburg, 1914.

NOTES ON THE GEOLOGY OF ZINC ORE DEPOSITS IN BOONE AND MARION COUNTIES, ARKANSAS. By Kirby Thomas. (Gift of Author.)

New Books on Non-Metallic Minerals

CHEMIE UND TECHNOLOGIE DER NATÜRLICHEN UND KUNSTLICHEN ASPHALTE. Ed.

2. By Hippolyt Köhler and E. Graefe. Braunschweig, 1913.

SHALE OILS AND TARS AND THEIR PRODUCTS. By W. Scheithauer, translated from the German by Charles Salter. London, 1913.

METALLURGICAL COKE. (Technical Paper 50, U. S. Bureau of Mines.) Washington, 1913.

NOTES ON THE PREVENTION OF DUST AND GAS EXPLOSIONS IN COAL MINES. (Technical Paper 56, U. S. Bureau of Mines.) Washington, 1913.

OIL FUEL. By Vivian B. Lewes. London, 1913.

USE AND MISUSE OF EXPLOSIVES IN COAL MINING. (Miners' Circular 7, U. S. Bureau of Mines.) Washington, 1913.

New Books on General Subjects

AMERICAN FERTILIZER HAND BOOK, 1913. Philadelphia, 1913.

AMERICAN YEAR BOOK, 1913. New York, 1914.

BIBLIOGRAPHIE DER DEUTSCHEN ZEITSCHRIFTEN LITERATUR. Band XXXII A. Leipzig, 1913.

ENGINEERING INDEX, 1913. New York, 1914.

EXPENSIVE EXPERIMENT. The Hydroelectric Power Commission of Ontario. By R. P. Bolton. New York, 1913. (Gift of Author.)

METAL STATISTICS, 1914. 7th ed. New York, American Metal Market Co., 1914. (Gift of Publisher.)

NEW YORK TIMES INDEX. Oct.-Dec., 1913. New York, 1914.

PATENTS, TRADE-MARKS, DESIGN PATENTS. By H. C. Thomson, Boston, 1913.

THE WORLD ALMANAC, 1914.

UNIVERSAL ELEMENTS AND THEIR PRIME COMBINATIONS. By Julius L. Hornig. Jersey City, 1913. (Gift of Author.)

Company Reports

BRUNSWICK CONSOLIDATED GOLD MINING Co. Annual Report for year ended Jan. 22, 1914. San Francisco, 1913. (Gift of Company.)

Trade Catalogues

- AMERICAN STEEL & WIRE Co., Chicago, Ill.
American Wire Rope News. Oct., 1913.
- CHICAGO PNEUMATIC TOOL Co., Chicago, Ill.
Bull. 149. Chicago portable mine hoist. Oct., 1913.
- DEISTER MACHINE Co., Fort Wayne, Ind.
Preliminary Bulletin. Jan., 1914.
Deister Machine Co.'s Classifier.
- FRANKLIN MOORE Co., Winsted, Conn.
Chain blocks, trolleys, hand-power cranes.
- HARRIS-STEVENS Co., Pittsburg, Pa.
Stevens Centrifugal Mine Fan.
Modern Mine Cars.
- LAIDLAW-DUNN-GORDON Co., Cincinnati, O.
Information Bull. No. 22. Air compressor efficiency. Jan., 1914.
- LESCHEN, A. & SONS ROPE Co., St. Louis, Mo.
Leschen's Hercules. Feb., 1914.
- MANITOWOC ENGINEERING WORKS, Manitowoc, Wis.
Bull. No. 156. Dryers.
- MIDVALE STEEL Co., Philadelphia, Pa.
Catalogue of mining wearing parts and smelter castings. Nov., 1912.
Catalogue No. 27. Rolled Steel Wheels. April, 1910.
Catalogue of steel-tired wheels. (Wheel Catalogue No. 1.) 1910.
- NEW YORK ENGINEERING Co., New York, N. Y.
Dredges and gold dredging (Empire). 68 pp.
Catalogue "G." Empire prospecting drill. 46 pp.
- SPARTA IRON WORKS Co., Sparta, Wis.
The Sludge Bucket. Feb., 1914.
- THOMAS, A. H. Co., Philadelphia, Pa.
Instruments of precision for the graphic study of the circulation. 12 pp.
Syringes for bacteriological work.
- WEBSTER MFG. Co., Tiffin, O.
Webster Method. Jan., 1914.

MEMBERSHIP

NEW MEMBERS

The following list comprises the names of those persons who became members during the month of February, 1914:

Members

- ASANO, KOSAKU, Vice-Mgr..... Ashio Copper Mine, Shimozuke, Japan.
 BIRD, FRANK H., Constr. Engr..... E. 417 Sixteenth Ave., Spokane, Wash.
 COLES, HENRY O., Chem..... Copper Queen Cons. Min. Co., Bisbee, Ariz.
 COLLEY, HYLTON H., Met..... Copper Queen Cons. Min. Co., Douglas, Ariz.
 DALEY, MITCHELL J., Mill Supt..... Utah Apex Min. Co., Box 753,
 Bingham Canyon, Utah.
 FISHER, GEORGE EDWARD, Director, 3d Vice-Pres., Grasselli Chemical Co.,
 1581 East 115th St., Cleveland, Ohio.
 FRASER, EVERETT L., Mill Supt..... Tightner Mines Co., Alleghany, Cal.
 FRASER, WILLIAM L., Min. Engr..... North Star Mines, Grass Valley, Cal.
 FROLLI, ALBERT W., Min. Engr..... 216 North Main St., Salinas, Cal.
 GEARHART, FRANK B., Chief of Smelter Dept., N. J. Zinc Co.,
 405 Columbia Ave., Palmerton, Pa.
 GILMAN, WALTER, Min. Engr..... 518 Walnut St., Philadelphia, Pa.
 HAMILTON, ALEXANDER K., Pres., M. H. Treadwell Co. of Ill.,
 72 W. Adams St., Chicago, Ill.
 HILL, A. STANLEY, Assayer..... Hecla Min. Co., Box 102, Gem, Idaho.
 HILTON, HUGH G., Asst. Supt..... Penn Iron Co., Y. M. C. A. Bldg., Erie, Pa.
 HINN, WILLIAM H., Min. Engr..... Hibbing, Minn.
 HOUSE, ALLEN CURTIS, Iron Ore Dept., M. A. Hanna & Co.,
 Leader-News Bldg., Cleveland, Ohio.
 KEE, HARRY ATWOOD, Supt..... Nipissing Min. Co., Ltd., Cobalt, Ont., Canada.
 KILIANI, RICHARD B. T., Sec., Hardinge Conical Mill Co., 50 Church St.,
 New York, N. Y.
 LEVY, ARTHUR GARFIELD, Met. Chem..... 1927 Madison Ave., New York, N. Y.
 LLOYD, JOHN, Efficiency Engr..... 29 Susquehanna St., Wilkes-Barre, Pa.
 LYON, GEORGE J., Cons. Engr., Asst. Prof. Civ. Engrg., Union Coll., Schenectady, N. Y.
 MCGEE, WILLIAM J., Attorney at Law; Mine Operator; Asst. Treas.,
 U. S. Sub-Treasury, San Francisco, Cal.
 MARSHALL, GEORGE B., Min. Engr..... Care Mina La Union, Miramar, Costa Rica.
 MARSHALL, NEWTON C., Min. Engr..... Winona Copper Co., Winona, Mich.
 MOORE, STANLEY R., Min. Engr..... Foreman Success Mine,
 Success Mining Co., Wallace, Idaho.
 OTTO, HENRY H., Division Engr...Lehigh Valley Coal Co., 11 St. Clements St.,
 Wilkes-Barre, Pa.
 PACKARD, HENRY JESSUP, Geol., N. Y. & Bermudez Co., Port of Spain,
 Trinidad, B. W. I.
 PULLEN, ERNEST F., Min. Engr., Mine Mgr., Alexo Nickel Mine, Iroquois Falls,
 Ont., Canada.
 RAY, JAMES CHANDLER, Min. Geol..... 1235 Webster St., Palo Alto, Cal.
 ROCCA, ANDREW, JR., Engr..... Snow Storm Min. Co., Larson, Idaho.
 SHEPARD, FREDERICK NEWTON, Mill Supt..... New Jersey Zinc Co., Franklin, N. J.
 SMITH, CHARLES ALBERT, Asst. Min. Engr..... Natomas Cons. of Cal.,
 115 Fell St., San Francisco, Cal.
 TWEEDY, ANDREW M., Min. Engr..... Room 337, 25 Broad St., New York, N. Y.
 WALTERS, RAY E., Min. Engr., Asst. Mgr., Snow Storm Mining Co., Larson, Ida.
 WANVIG, JOHN D., JR., Min. Engr., Supt..... Three R Mines, Patagonia, Ariz.
 WHITE, JAMES B., Min. Engr..... 121 S. Galt Ave., Louisville, Ky.
 WILLIAMS, ARTHUR, Elec. Engr..... 55 Duane St., New York, N. Y.
 WILLIAMS, HORACE E., Geol..... Servico Geologico, Ministerio de Agricultura,
 Rio de Janeiro, Brazil, So. America.
 YAKE, ELMER ELLSWORTH, Blast Furnace Dept., Penn. Steel Co.,
 363 Locust St., Steelton, Pa.

Associate

JENNEY, WARREN, Met. Accountant, Anaconda Copper Min. Co., Anaconda, Mont.

Junior Members

BERNHARD, DURWARD I., Student.....Casa Grande, Ariz.
 BROOKE, LIONEL, Student.....Colo. School of Mines, Golden, Colo.
 GRAHAM, HERBERT, Student.....633 Linden Ave., Johnstown, Pa.
 KRAUSE, WALTER B., Student.....436 Cherokee St., So. Bethlehem, Pa.
 LAWALL, CHARLES ELMER, JR., Student.....519 Kurtz St., Catasauqua, Pa.
 LAWSHE, VERNER THATCHER, Student.....334 Broad St., Bethlehem, Pa.
 LIEBIG, JOHN ORTH, Student.....821 Delaware Ave., So. Bethlehem, Pa.
 LYDEN, JOSEPH P., Student.....628 S. Wyoming St., Butte, Mont.
 McMAHON, BRANDON P., Student.....443 E. Broadway, Butte, Mont.
 MERWIN, MILES HENDERSON, Student.....506 Delaware Ave., So. Bethlehem, Pa.
 NEWELL, ARTHUR, Student.....625 W. Johnson St., Madison, Wis.

CANDIDATES FOR MEMBERSHIP

The following persons have been proposed during the month of February, 1914, for election as members of the Institute. Their names are published for the information of members and associates, from whom the Committee on Membership earnestly invites confidential communications, favorable or unfavorable, concerning these candidates. A sufficient period (varying in the discretion of the Committee, according to the residence of the candidate) will be allowed for the reception of such communications, before any action upon these names by the Committee. After the lapse of this period, the Committee will recommend action by the Board of Directors, which has the power of final election.

Members

Asaka Abe, Satsuma, Japan.

Proposed by Benzo Katsura, Kennosuke Tsujimoto, Tadashi Inoué.

Born, 1879, Nagato, Japan. 1904, Graduated Mining and Metallurgical Department, Tokyo Imperial University; Degree "Kogakushi." 1904, Mining and Metallurgical Engineer of Zuiho Gold Mine, Taiwan, belonging to Fujita & Co., Osaka. 1907, Chief of Zuiho Gold Mine. 1909, Mining Engineer in Main Office of Fujita & Co., Osaka.

Present position: 1913 to date, Chief Engineer of Yamagano Gold Mine, Satsuma, Japan.

Henry H. Adams, Jr., New York, N. Y.

Proposed by J. E. Johnson, Jr., William C. Dickerman, Lewis W. Francis.

Born, 1873, Cleveland, Ohio. 1891, Graduated from St. Paul School, Concord, N. H. 1891, Entered Yale Univ. acad. course. 1906-13, President of Colonial Iron Co., engaged in manufacture of pig iron, mining of coal and iron ore in Pennsylvania and New York. 1906-14, President of Old Sterling Iron & Mining Co. of New York.

Present position: 1900 to date, Prop. of Henry H. Adams & Co., and interested in the companies above named as director and large stockholder.

Newell G. Alford, Earlington, Ky.

Proposed by Howard N. Eavenson, Frank D. Rash, E. O. Foote.

Born, 1887, Philadelphia, Pa. Complete secondary education in Friends' Schools of Philadelphia. 1901-06, College preparatory work; graduated Friends' Central School, Philadelphia, Pa. 1909, Graduated from Swarthmore College, Swarthmore, Pa.; A. B. 1907, Summer work in Engineering Dept. of United States Coal & Coke Co., Gary, W. Va. 1908, Summer work with above company (included work on bee-hive ovens for Coke Com. of United States Steel Corp'n.). 1909, By-Product Coke Plant, Illinois Steel Co., Joliet, Ill.

Present position: Asst. Engineer, St. Bernard Mining Co., Earlington, Ky.

Herbert Durham Allan, Umaria, Central India.

Proposed by W. A. Freymuth (two additional signatures required).

Born 1880. 1895, Matriculation, Madras Univ. 1897, F. A., Madras Univ. 1899-1903, Thomason College of Civil Engineering, Roorkee, India. Silver Medal Surveying. 1914, Student, (1) I. C. S. 1st class Manager's Certificate, (2) U. M. S. Cardiff, (3) Cambrian Mining School. (4) Electrical Engineer Institute, London. 1903-04, Government Gun Carriage Factory, Jubbulpore. 1904-05, Surveyor, Rewah State Collieries. 1905-13, Overman Rewah State Collieries.

Present position: Assistant Manager, Rewah State Collieries, Umaria.

F. M. Anderson, Berkeley, Cal.

Proposed by W. C. Mendenhall, Frederick P. Burrall, George Otis Smith.

Born, 1863, Phoenix, Ore. 1889, Graduated Willamette Univ., Oregon; A. B. 1895, Graduated Stanford Univ., California; B. A. 1897, Graduated Univ. of California; M. S. 1900-1902, California State Mining Bureau. 1902-1911, Geologist Southern Pacific Co.

Present position: 1911 to date, Consulting Geologist and oil lands and properties.

Irving Anderson, Wallace, Idaho.

Proposed by Rush J. White, George W. Roddewig, J. B. Wilson.

Born, 1881, Idaho Springs, Colo. 1898, Graduated Wallace High School, Wallace, Idaho. 1899, Graduated Palo Alto High School, Palo Alto, Cal. 1903, A. B. Stanford University. 1903-14, General surveying and engineering practice. 1905-14, Consulting Engineer, Hercules Mining Co., Burke, Idaho.

Present position: General Engineering and Consulting Engineer, various properties, Coeur d'Alene mining district.

James Willoughby Anderson, New York, N. Y.

Proposed by F. L. Grammer, N. V. Hansell, Herbert B. Cox.

Born, 1867, Norfolk, Va. Grad. High School of District of Columbia in 1885. 1889, Grad. from Lehigh University, School of Mines and Metallurgy; B. S. 1890, Post-Graduate degree of Engineer of Mines from Lehigh University. 1904, Grad. Georgetown University; LL.B. Member of the Bar of the District of Columbia. First employed in Engineering Corp. of D. of C. Admitted to U. S. Patent Office in 1890, by regular civil service examination; promoted to principal examiner in U. S. Patent Office in 1904; during service in Patent Office, had entire charge of inventions relating to optics, internal combustion engines, miscellaneous heat engine plants, etc. Have practiced as Attorney for four years.

Present position: Associated with the firm of Duell, Warfield & Duell, New York, N. Y.

Maurice W. Bacon, Butte, Mont.

Proposed by Horace V. Winchell, E. H. Wilson, Fred T. Greene.

Born, 1870, Greenwich, N. J. 1883-88, Westtown Preparatory College, Westtown, Pa. General education. 1889-94, Northern Pacific R. R. Co., Traffic Dept. 1895-98, Oregon Short Line, Traffic Dept. 1898-1908, F. Augustus Heinze, Montana Ore Reduction Co. 1909-14, Davis-Daly Copper Co., Stewart Mining Co.

Present position: Gen. Manager, Stewart Mining Co.

Raymond F. Bacon, Pittsburg, Pa.

Proposed by Henry Krumb, S. L. Goodale, W. H. Aldridge.

Born, 1880, Muncie, Ind. 1899, B. S., De Pauw Univ. 1900, A. M., De Pauw. 1904, Ph.D., Univ. of Chicago. 1899-1900 Instructor in Chemistry, De Pauw Univ. 1900-01, Prof. of Chemistry, Vincennes Univ. 1902-04, Fellow in Chemistry, Univ. of Chicago. 1904-05, Mining work in Colo. 1905-10, Government chemist, Bureau of Science, Manila, P. I. 1910-11, Asst. chemist, Bureau of Chemistry, Washington, D. C.

Present position: 1911 to date, Director, Mellon Institute of Industrial Research.

Hamilton Wallace Baker, New York, N. Y.

Proposed by Victor C. Alderson, C. L. Colburn, Robert M. Keeney.

Born, 1888, Media, Pa. 1902, Media Primary, Grade and High Schools. 1902-05, Philips Exeter Academy, grad. 1905. 1906-09, Colorado School of Mines. 1910-11, Grad. as Engineer of Mines. 1909, Surveyor and Assayer, Cornucopia Mines Co., Cornucopia, Ore. 1910, In charge of excavation work testing plant, Colorado School of Mines, Golden, Colo. 1911, Supt. Western Mining, Milling and Leasing Co., near Salida, Colo. 1911-13, Supt. of A. B. C. Mine, Rio Dolores Mine and Lillia D Mines of Rico and Mary Jane Mining Co., Denton, Colo.

Present position: 1913 to date, Cons. Engr. with B. B. Lawrence, New York, N. Y., and Genl. Supt. Buffalo Valley Gold Mining & Leasing Co., Stonehouse, Nev.

Harry Brewster Barling, New York, N. Y.

Proposed by F. Lynwood Garrison, J. F. Kemp, E. G. Spilsbury.

Born, 1879, Brooklyn, N. Y. 1903, With Pike Mfg. Co., Pike, N. H., various positions in their quarries. 1904, With Etowah Mining Co., Ga., assistant manager and manager. 1905-06, Superintendent, Columbus Borax Co., Ventura Co., Cal., owned by M. Calm and Bro., New York. 1907-09, Assistant to H. E. Crawford, examining engineer for Estate of Marcus Daly. 1909-10, Engineer at mine of San Antonio Copper Co., Sonora, Mex. 1909, Examining Engineer for Pacific Smelting & Mining Co., Sonora, Mex. 1911-12, Manager, New York & Honduras Rosario Mining Co., Honduras, C. A.

Present position: 1913 to date, Examining Engineer for Breitung & Co., Ltd., New York.

Arthur F. L. Bell, San Francisco, Cal.

Proposed by George A. Packard, Frederick P. Burrall, Robert Linton.

Born, 1861, London, England. 1868-1879, Grammar and private Schools, San Francisco, Cal. Technical education self-acquired. About 1880, Mech. Engr., San Francisco Tool Co., afterward Chief Engineer. 1892, Resident Mgr. and Engr., Alcatraz Asphalt Co., Santa Barbara, Cal. 1901, Field Mgr., Associated Oil Co. of California.

Present position: Chief Engr., Associated Oil Co. of California.

Daniel George Bisset, Hosmer, B. C., Canada.

Proposed by B. L. Thorne, Lewis Stockett, H. E. T. Haultain.

Born, 1882, Goderich, Ont., Canada. 1902, 2nd Class certificate, Regina, Sask.; 1st class work in Edmonton High School. 1906, Year I Arts, McMaster University. 1907-11, Student, Min. Engrg., Ontario School of Practical Science, Toronto. 1907-11, Faculty of Applied Science and Engineering, Univ. of Toronto; B. Sc. 1911, Assayer, Dome Mine. 1912, Sampler, Hollinger Mine; Asst. Engr., Bankhead, Alta., C. P. R. Mine.

Present position: 1913 to date, Asst. Engr., Hosmer, B. C.

Charles Gilman Bowen, Grass Valley, Cal.

Proposed by William Hague, Robert H. Bedford, Arthur B. Foote.

Born, 1886, Boston, Mass. 1900-06, Noble and Greenoughs' School, Boston, Mass. 1906-10, Harvard University. 1907-10, Harvard Mining School. 1910-12, Underground work at Calumet & Hecla Mining Co. 1912, Five months underground work at Bisbee, for Calumet and Arizona; two months underground work at North Star Mines Co., Grass Valley. 1913, Shift man at North Star Cyanide plant.

Present position: 1914 to date, Timekeeper, North Star Mines Co., Grass Valley, Cal.

David F. Boyd, Washington, D. C.

Proposed by Anthony F. Lucas, Ralph Arnold, J. A. Holmes.

Born, 1876, Baton Rouge, La. 1882-90, Common and private schools. 1890-93, Academic, Kentucky Military Institute and Alabama Polytechnic Institute. 1893-97, U. S. Naval Academy. 1897-1914, Mainly at sea in discharge of duties. Courses of instruction on technical subjects for limited periods at the Torpedo Station, Drexel Institute, Compass Office and War College. 1893-1914, In general, the routine duties of a Naval Officer. Have performed the usual percentage of duty as Marine Engineer (particularly in torpedo boats and destroyers); was Inspector of Electrical Appliances at Cramp's Shipyard, 1907-09. Now in charge of petroleum and coal subjects, and administration of Alaskan coal investigations.

Present position: Lt. Com., U. S. Navy, on duty in the Bureau of Steam Engineering.

Samuel L. Boyer, Spokane, Wash.

Proposed by L. K. Armstrong, J. C. Haas, E. P. Spalding.

Born, 1854, Bellville, Mich. 1870-73, High School, Bellville, Mich. Engineering experience gained in different engineering operations on railway surveys. Assaying learned at mills of mines and later while in charge of mining operations. 1873-87,

Railway construction. 1885-87, Road Master, Supt. Roadway and Bridges and Supt. of Construction, Colo. Midland Ry. 1887-93, Mine Supt. and Mgr. at Aspen, Colo. Examinations of mines, Mex. and So. Amer. More recently Supt. or Mgr. of mines and milling operations in Northwest.

Present position: Mgr. Mike Horse Mining Co., Lewis & Clark Co., Mont.

William David Brennan, Cheyenne, Wyo.

Proposed by Frank A. Manley, Frederick H. Bostwick, C. L. Colburn.

Born, 1877, Malone, N. Y. 1900, Ph.B., Sheffield Scientific School, Yale Univ. 1901, Civil Engineer, Street Department, City of Boston. 1901-06, Mining Engineer, Union Pacific Coal Co. 1906-08, Mining Engineer, Superior Coal Co. 1908-12, Superintendent, Superior Coal Co. 1912-13, General Superintendent, Superior Coal Co.

Present position: 1913 to date, Assistant General Manager, The Union Pacific and Superior Coal Companies.

George A. Carroll, Seattle, Wash.

Proposed by George W. Otterson, Milnor Roberts, Joseph Daniels.

Born, 1866, Benicia, Cal. 1886, Practical experience with quartz and placer mining companies. 1886-88, Bunker Hill & Sullivan Mining Co., Wardner, Idaho. 1889-91, Tiger Mining Co., Burke, Idaho. 1892-1900, Copper Queen Mining Co., Bisbee, Ariz. 1902-03, Rodman Bay Mining Co., Rodman, Alaska. 1904-05, Copper Mt. Mining Co., Pr. Wales Island, Alaska. 1906, Standard Copper Co., Valderf, Alaska. 1907, Perseverance Mining Co., Juneau, Alaska. 1910-11, Santa Rosa Mining Co., Keeler, Cal.

Present position: 1913 to date, Asst. to G. W. Otterson, Genl. Mgr., Kildare Mining Co., Manson, B. C.

Walter Barclay Chidester, Dedrick, Cal.

Proposed by H. A. Morrison (two additional signatures required).

Born, 1884, Memphis, Tenn. Grammar and High School in Tacoma, Wash., 1903, Grad. Tacoma High School, and entered State College of Washington, Pullman, Wash., in same year. 1907, Grad. State College of Washington; B. S. in Mining Engineering. 1904-06, Underground work in Morning, Hecla, and Standard Mines, Cœur d'Alène district, Ida. 1908-10, Millman, Sweeney and Morning Mills of Federal M. & S. Co., at Sweeney and Mullan, Ida.; chairman for N. P. Ry. survey, Mandan, N. D. 1910-11, Millman in Goldfield Cons. and in Nevada-Goldfield Reduction Works, Goldfield, Nev. 1911-12, Draftsman, Engineer, Assayer for Tonopah Belmont Dev. Co., Supt. Dreisam Mine (T. B. D. Co.); Cyanide Mill, Globe Cons. Mining Co., Dedrick, Cal.

Present position: Engineer and Shift Boss, Jim Butler Mine, Tonopah, Nev.

William A. Cochran, Pottsville, Pa.

Proposed by Charles Enzian, J. Elmer Jones, James M. Humphrey.

Born, 1862, Pottsville, Pa. 1879, Grad. Pottsville High School. 1879-85, Private instruction. 1879-85, Employed by P. & R. C. & I. Co., L. V. R. R. Co. and A. B. Cochran. 1885-89, A. C. Cochran, being admitted to partnership A. B. Cochran & Son April 1, 1889, and sole owner since death of A. B. Cochran.

Present position: From 1905 to date, Mining Engineer for various companies, etc.

George Thomas Coffey, Oakland, Cal.

Proposed by C. H. Munro, James S. Wyatt, F. R. Short.

Born, 1871, Nevada County, Cal. 1876-90, Grammar school and private instruction. 1889-94, Milton Mining & Water Co., Malakoff Gravel Mfg. Co., Nevada Co., Cal. 1894-97, Caribou Con. Hydraulic Min. Co., Caribou, B. C., Can. 1898-1914, Klondyke Dist., Y. T., Yukon Gold Co.

Present position: Supt. Hydraulic Operations, Yukon Gold Co., Dawson, Y. T.

Paul Benjamin Davis, Organ, N. M.

Proposed by N. J. Welsh, C. B. Johnson (one additional signature required).

Born, 1873, Reading, Pa. 1895, Undergraduate, Lehigh Univ., in Chemical Engineering. 1895-1900, engaged in general engineering work, Pennsylvania. 1900-06, Assistant City Engineer, Reading, Pa. Subsequently engaged in mining in New Mexico.

Present position: Gen. Mgr., Philadelphia Mining Co., Organ, N. M. Gen. Mgr., Jarilla Copper Co., Orogrande, N. M.

Ralph Woolman Deacon, Sudbury, Ont., Canada.

Proposed by Lawrence Addicks, Herman A. Prosser, E. A. C. Smith.

Born, 1878, Mount Holly, N. J. 1893, College preparatory, Mt. Holly Academy. 1898, B. S. in M. E., Univ. of Pennsylvania. 1898-99, General Electric Co., outside construction. 1899-1900, Wm. Sellers & Co., Phila., Crane Dept. 1900-01, Penna. Iron Works, Phila., in Engine Dept. 1901-05, Balto. Copper Smelting & Rolling Co., Canton, Md., as engineer, foreman and dept. supt. General metallurgical experience in connection with copper smelting and refining. 1905-06, Supt. James Barker Iron Foundry, Phila. 1906, Asst. to Gen. Mgr., Penna. Glass Sand Co., Lewistown, Pa. 1907-13, Asst. Supt., U. S. Metals Refining Co., Chrome, N. J.

Present position: March 1, 1913, to date, Met. Supt., British America Nickel Corp., Ltd., Sudbury, Ont., in charge of design, construction and operation of refining for electrolytic recovery of nickel.

John T. Dillon, Anyox, B. C.

Proposed by A. J. Bone, F. F. Frick, Frederick Laist.

Born, 1871, Ireland. Common School. 1895-11, Anaconda Copper Mining Co., Washoe Smelter. Granby Cons. Mining, Smelting and Power Co., Grand Forks and Anyox, B. C.

Present position: Converter Foreman, Anyox, B. C.

Everett Drennen, Jenkins, Ky.

Proposed by Howard N. Eavenson, E. O'Toole, H. V. Hesse.

Born, 1881, Minneapolis, Minn. 1900-03, University of Michigan, Engrg. Dept. 1904-07, Cornell University, Civil Engrg. Dept.; C. E. 1903-04, Maintenance of Way Dept., P. R. R. 1907, Supervisor of Road Construction, Belmont County, O. 1907-13, Supt. Power and Mechanical Dept., Consolidation Coal Co. 1910-13, Genl. Mgr., Fairmont Min. Machinery Co.

Present position: 1913 to date, Mgr., Consolidation Coal Co., Elkhorn Division.

Paul Drorkovitz, London, E. C., England.

Proposed by Anthony F. Lucas, David T. Day, M. R. Campbell.

Born, 1858, Russia. University of Moscow. Editor *Petroleum Review*. (More information is required.)

Present position: Technical adviser, petroleum expert.

Theodore Saunders Dunn, Rolla, Mo.

Proposed by G. H. Cox, C. R. Forbes, H. A. Buehler.

Born, 1881, Maryville, Mo. 1900, Grad. Waukegan, Ill., High School. 1905-06, Lake Forest College, Lake Forest, Ill. 1906-10, Missouri School of Mines, Rolla, Mo.; B. S. 1910-11 Engrg. Dept. Savanna Copper Co., Silver City, N. M. Summer 1911, Land Surveying, Zarella Co., Tex. 1911-12, Min. Engr., Chinook Coal Co., Lethbridge, Alta., Can. 1912, Timberman, Ariz. Copper Co., Morenci, Ariz. 1912-13, Instrumentman, Construction Dept., Anaconda Copper Co., Boston & Montana Reduction Dept., Great Falls, Mont.

Present position: Graduate Student, Missouri School of Mines.

James Porter Evans, Denver, Colo.

Proposed by E. W. Walter (two additional signatures required).

Born, 1860, Zanesville, O. 1867-76, Public School, Hannibal, Mo. General knowledge acquired in eighteen years' service with Colorado Iron Works Co., in office, works and field; erecting mills and smelters. 1876-81, Office Work, H. & St. J. R. R., Hannibal, Mo. 1881-95, Office, and Auditor of Express, D. & R. G. R. R., Denver. 1895-98, Auditor, Colo. Iron Works, Denver. 1898-1909, In charge of erection of mills and smelters for Colo. Iron Works Co.

Present position: 1910 to date, Vice-Pres. and Gen. Mgr., Colo. Iron Works Co.

William Edward Fohl, Pittsburg, Pa.

Proposed by S. A. Taylor, W. G. Wilkins, E. W. Parker.

Born, 1871, Martinsburg, W. Va. 1891, Grad. Pa. State Normal School, Shippensburg, Pa. 1892, Special work in same school. 1892-1904, S. M. Taylor, Mining Engr., Pittsburg, Pa., in examination, development and operation of bituminous coal properties. 1897-98, J. H. Somers Fuel Co.

Present position: 1904 to date, Consulting Mining Engr. General consulting practice in bituminous coal mining.

Michel Fort, Lima, Peru.

Proposed by (three signatures required).

Born, 1869, Lima, Peru. 1890, Mining Engineer at the School of Engineers of Peru. Professor of Metallurgy and Ore Dressing 1890-95, Backus & Johnston Co. Casapalca, Peru. 1895-96, Victoria amalgamating Plant. 1896-97, Aguas Calientes Mining and Dressing, Casapalca, Peru. 1897-1904, Professor of Metallurgy and Dressing Ores, Lima, Peru. 1901-04, Director of the School of Engineers, Lima, Peru. 1897-1904, Consulting engineer.

Present position: Director School of Engineers, Lima, Peru.

Dr. Hans Fousterting, Perth Amboy, N. J.

Proposed by E. Gybbon Spilsbury, Edward L. Young, Louis Ruhl.

Born, 1872, Dresden, Germany. 1891-94, University Heidelberg, Kiel. 1894, Ph. D. 1895, Technical Director A. Schneider & Co., Pretoria, Transvaal. 1897-1900, Chemist with Deutsche Gold & Silver Scheide Co., Frankfurt a/M. Technical Director, Chemistry Fabrik, Terra, Mecklenburg

Present position: 1900 to date, Chemist, Roessler & Hasslacher Chemical Co.

Douglas Warner Franchot, Tulsa, Okla.

Proposed by (three signatures required).

Born, 1880, Olean, N. Y. 1899-1903, Yale, Sheffield Scientific School; Ph. D.

Present position: 1903 to date, Producer of Crude Petroleum in various oil fields of U. S., Owner and Supt., D. W. Franchot & Co.

Heinrich J. Freyn, Chicago, Ill.

Proposed by E. G. Spilsbury, F. A. Vogel, A. M. Tweedy.

Born, 1876, Blansko, Aust. 1882-86, Public Schools, Prague, Aust. 1886-93, Realschule, Prague, Aust. 1893-99, Technische Hochschule, Univ.; M. E. 1899-1901, Breisfeld Danek, Prague, Aust. Gas Engine Engr. in charge. 1901-03, Gas Engine Engr., John Cockerill Co., Seraing, Belgium. 1903-06, Wellman-Seaver-Morgan Co., Cleveland, Ohio. 1906-11, Asst. Engr. of Construction, Ill. Steel Co., So. Chicago, Ill. 1911-13, Consulting Engr., Allis-Chalmers Mfg. Co., Milwaukee, Wis.

Present position: Third Vice-President, H. Koppers Co., Chicago.

William Hiram Fursman, Henryetta, Okla.

Proposed by Eugene McAuliffe, Franklin Bache, H. H. Stoek.

Born, 1879, El Paso, Ill. 1904, Civil Engineering Graduate of the University of Illinois. 1902-03, Draftsman, Love Bros. Architectural Iron Works, Aurora, Ill. 1904-05, Railroad location and construction, Missouri, Oklahoma & Gulf R. R., Muskogee, Okla. 1905-10, Division Engineer, Dering Coal Co., Chicago, Ill. 1910-11, Supt. Const., Oklahoma Coal Co., Dewar, Okla.

Present position: Coal mining and Mining Engineer, Henryetta, Okla.

Eugene Allen Gilmore, Spokane, Wash.

Proposed by L. K. Armstrong, E. P. Spalding, F. A. Thomson.

Born, 1885, Effingham, Ill. 1902-03, Washington University, St. Louis, School of Engineering. 1904-05, Armour Inst. of Technology, Chicago, Ill. 1899, Miller Construction Co. 1901-02, Mechanical dept., Pennsylvania R. R. Co. 1908-13, Mechanical and Construction Engineer, Westinghouse, Church, Kerr, & Co., New York.

Present position: Vice-President, Federal Machinery Co., Spokane, Wash.

Robert James Glendining, Salt Lake City, Utah.

Proposed by James C. H. Ferguson, Alfred Frank, J. Labarthe.

Born, 1866, Jersey City, N. J. 1882, Public Schools, Jersey City, N. J. 1882-87, Hasbrouck Institute, Jersey City, N. J. 1888-97, Geo. M. Scott & Co., Salt Lake City, Utah. 1897-1902, Mine & Smelter Supply Co., Salt Lake City, Utah. 1902-05, Allis-Chalmers Co., Chicago, Ill., Salt Lake City District Manager. 1905-08, Chalmers & Williams, Chicago, Ill., Salt Lake City District Manager.

Present position: 1908 to date, R. J. Glendining & Co.

Ernest G. Gnaedinger, Wallace, Idaho.

Proposed by Rush J. White, George W. Roddewig, J. B. Wilson.

Born, 1882, Montreal, Canada. Grammar and High School education at Montreal, Canada. 1904, Graduate of McGill University, Montreal, with degree of B. S. as Mining Engineer. 1904-05, University at Leipzig and Mining School at Freiberg, Saxony, Germany. 1906-14, General mining engineering practice in the Cœur D'Alenes, Idaho.

Present position: General practice.

George Edward Goodspeed, Jr., Corvallis, Ore.

Proposed by H. M. Parks, A. M. Swartley, Charles E. Locke.

Born, 1887, Boston, Mass. 1900-06, Roxbury Latin School, Boston (six year course). 1906-10, Mass. Inst. of Technology, Course in Mining Engineering; S. B. 1911, Private assistant to Prof. R. H. Richards at Tech. 1912, Assistant in the Geological Department of Tech.

Present position: 1913 to date, Instructor in the School of Mines at the Oregon Agricultural College, also assistant geologist for the Oregon Bureau of Mines and Geology.

Thomas Leo Greenough, Spokane, Wash.

Proposed by F. A. Ross, E. P. Spalding, L. K. Armstrong.

Born, 1884, Clinton, Mont. 1899, University of Montana, preparatory school. 1902, University of Montana. 1906, B. S. in Engineering. 1906, Supt., Wren & Greenough Construction Co. 1907-08, Supt. Construction, Red Canyon Mg. Co. 1908-10, Manager, Snow Storm Mining Co.

Present position: General Manager, Snow Storm Mg. Co.

George B. Hadesty, Pottsville, Pa.

Proposed by Douglas Bunting, W. J. Richards, Charles Enzian.

Born, 1866, Frackville, Pa. 1872-83, Public schools. 1883-85, Private tuition in mathematics. 1883-98, P. & R. C. & I Co., as chairman, rodman, transitman and engineer. 1898-1905, L. & W. B. C. Co. as Division Engineer and Superintendent.

Present position: 1905 to date Supt., P. & R. C. & I Co.

William J. Hallet, Rock Springs, Wyo.

Proposed by Frank A. Manley, Regis Chauvenet, F. W. Traphagen.

Born, 1880, Colorado Springs, Colo. 1891-1900, Denver Public Schools. 1905, E. M., Colorado School of Mines, Golden, Colo. 1903, Asst. Engr., Union Pacific Railroad. 1905, Asst. Supt. and Assayer, St. Jacobs Mine, Lake City, Colo. 1905-06, Mining, Timbering, Asst. Engr., etc., Boston & Montana Copper Co., Butte, Mont. 1906-09, Asst. Engr., Union Pacific Coal Co., Rock Springs, Wyo. 1909-11, Act. Chief Engr. Union Pacific Coal Co.

Present position: 1911 to date, Chief Engineer, Union Pacific Coal Co., Rock Springs, Wyo.

F. M. Handy, Pullman, Wash.

Proposed by L. K. Armstrong, F. A. Ross, Hallet R. Robbins, Francis A. Thomson.

Born, 1897, Guthrie Co., Iowa. 1905, A. B., Wheaton College, Wheaton, Ill. 1909-11, graduate study in geology at the University of Chicago. 1911, Asst. Field Geologist, U. S. G. S. 1912, Asst. Field Geologist, Minn. State Geological Survey. 1913 Asst. Field Geologist, Wash. State Geological Survey. 1910, Asst. Field Geologist, Ontario Bureau of Mines.

Present position; Asst. Professor of Economic Geology, Wash. State College.

Isaac Harter, Jr., Bayonne, N. J.

Proposed by H. M. Howe, D. S. Jacobus, J. E. Johnson, Jr.

Born, 1880, Mansfield, Ohio. 1891-93, St. Paul's School, Concord, N. H. 1893-95, Episcopal Academy, Philadelphia, Pa. 1895-97, St. Paul's School, Concord, N. H. 1897-1901, University of Pennsylvania; B. S. 1901-03, Aultman & Taylor Machinery Co., Mansfield, Ohio. Shop work in boiler construction. 1903-06, Superintendent for Aultman & Taylor Machinery Co., Boiler Dept. 1906-10, Superintendent, Barborton Works of Stirling Consolidated Boiler Co., later Babcock & Wilcox Co., Barborton.

Present position: 1910 to date, Superintendent, Bayonne Works, Babcock & Wilcox Co.,

Thomas Newell Havlin, Weir, Kan.

Proposed by C. A. Bohn, H. A. Guess, P. A. Mosman.

Born, 1884, Covington, Ky. 1898-1903, Bethel Military Academy, Warrenton, Va. 1904-08, Washington and Lee Univ., Lexington, Va.; B. S. 1908-09, Asst. Chemist, Armour & Co., East St. Louis, Ill. 1909-10, Chem., Morris & Co., East St. Louis, Ill. 1910-11, Asst. Gas Engineer, Laclede Gas Light & Power Co., St. Louis, Mo. 1911-12, Chem., St. Louis Sampling & Testing Works, St. Louis, Mo. Assayer and Millman, Florence Mining Co., Thompson, Mont. 1912-13, Chemist and Assayer of Federal Lead Co., Flat River, Mo.

Present position: Professor of Chemistry and Metallurgy, Kansas School of Mines and Metallurgy, Weir, Kan.

Alfred George Heggem, Pittsburg, Pa.

Proposed by H. B. Goodrich, J. J. Rutledge, O. U. Bradley.

Born, 1875, Salem, Ohio. 1881-92, Public Schools through High School, Massillon, Ohio. 1892-94, Case School of Applied Science, Cleveland, Ohio. 1894-97, Cornell University, Ithaca, N. Y.; M. E. 1900, Various engineering positions. 1900-03, Chief Engineer and General Superintendent, Russel Engine Co., Massillon, Ohio. 1904, Private engineering practice. 1905-12, Chief Engineer, Oil Well Supply Co., Pittsburg, Pa. 1912-13, Vice-President, Continental Supply Co., St. Louis, Mo.

Present position: Petroleum Engineer, U. S. Bureau of Mines.

Alexander J. Heindl, Bodaibo, Government of Irkutsk, Siberia.

Proposed by R. E. Smith, J. P. Hutchins, Edgar Rickard.

Born, 1884, Libau, Russia. 1901, Real School, Riga, Russia. 1902, Polytechnical School, Riga. 1904, Technological Institute, Tomak, Siberia. 1911, University of California; B. S. in Mining. 1904, Dredging, constructing and operating, Enissivsk, Siberia. 1905, Supt., Placer Mines, Bargouine. 1906, Miner, various mines California. 1911, Oiler, Natomas Cons. 1912, Geological Staff, Southern Pacific, San Francisco. 1913, Lena Taiga Syndicate, Bodaibo.

Present position: Asst. Field Engineer, Lena Taiga Syndicate, Bodaibo, Russia.

Axel Herman Helander, Youngstown, Ohio.

Proposed by C. S. Robinson, E. T. McCleary, H. S. Braman.

Born, 1864, Oingaker, Sweden. 1882, Graduate of Tech. College as Chemists Norrköping, Sweden. 1883, Chemical Laboratory, Sweden. 1885-88, Machine shop work, Bement & Miles, Philadelphia; Midvale Steel Company, Philadelphia, Pa. 1888-90, Draftsman, Midvale Steel; Geo. C. Howard Co. 1890-1900, Engineer, Mech. Southwark Foundry & Machine Co., Frank C. Roberts, Philadelphia. 1900-06, Chief Engineer, Colo. Fuel & Iron Co., Colorado. 1906-1912, Sales Engineer, Weston Machine Co.

Present position: Sales Manager and Consulting Engineer, William Tod Co., Youngstown, Ohio.

Joseph Wesley Henderson, Pittsburg, Pa.

Proposed by E. C. Potter, H. E. Field, Fred Crabtree.

Born, 1869, Millbrook, Ont., Canada. 1883, High School, Jackson, Michigan. 1888-94, Private instruction in Inorganic Chemistry while engaged in Laboratory work at South Chicago Steel Mills. 1901-02, Correspondence Course Mech. Eng. 1887-94, Laboratory, Illinois Steel Co. and Irondale Furnace Co. 1895-98, Laboratory and operating end, Griffin Wheel Co., Chicago, Ill. 1899, Laboratory and cupola operator, Crane Mfg. Co., Chicago, Ill. 1900-04, Metallurgist, then Supt., Maryland Car Wheel Works, Baltimore, Md. 1904-05, Supt., Central Car Wheel Co., Pittsburg, Pa. 1905-07, Built equipment and managed Butler Car Wheel Co., Butler, Pa.

Present position: 1907 to date, Vice-President, Gulick Henderson Co., Pittsburg, Chicago, New York.

L. B. Herr, Jr., Santiago, Cuba.

Proposed by George W. Pfeiffer, Edward H. Emerson, Charles F. Rand.

Born, 1890, Lancaster, Pa. 1898-04, Public School. 1904-07, Franklin and Marshall Academy, Lancaster, Pa. 1907-10, Franklin and Marshall College, Lancaster, Pa. L. B. Herr & Son, Lancaster, Pa. (clerk). 1910 Timekeeper, Penn. Water & Iron Co., McCall's Ferry, Pa. 1910-12, Chemist Ponupo Manganese Co., Santiago de Cuba.

Present position: Spanish American Iron Co., Santiago, Cuba.

George W. Hewitt, Wheeling W. Va.

Proposed by William O. Wood, Talbot E. Pierce, David T. Croxton.

Born, 1886, Cassopolis, Mich. 1908, Graduated University of Wisconsin; B. A. 1908-09, Chemist, Grasselli Chemical Co., Elizabeth, N. J. 1909-14, Riverside Wks., National Tube Co., Wheeling W. Va. Foreman Furnace Blower, Asst. Supt., and Supt., Blast-furnace Dept.

Present position: Supt., Blast-furnace Dept., Riverside Works, National Tube Co., Wheeling, W. Va.

Elwood Cheyney Hickman, East Helena, Mont.

Proposed by A. Eilers, F. M. Smith, G. C. Riddell.

Born, 1885, West Chester, Pa. 1903, High School, West Chester, Pa. 1908, B. S. Mines and Metallurgy, Penn. State College, Pa. 1908, N. R. Rambo, County Surveyor, West Chester, Pa. 1909, Nipissing Mining Co., Cobalt, Canada. 1910, Red Metal Mining Co., Butte, Mont. Horsky Coal Co., Painted Robe, Mont. 1911, Northwestern Metals Co., Helena, Mont. American Smelting & Refining Co., East Helena, Mont.

Present position: General Foreman, Sampling Dept., East Helena Plant, A. S. & R. Co.

Arthur J. Hiester, Tucson, Ariz.

Proposed by W. O. Borchardt, Frank L. Mason, Charles F. Rand.

Born, 1889, Chicago, Ill. 1904-07, Crane Technical High School, Chicago, 1907-12, Colorado School of Mines, Mining Course, specializing one year in Metallurgy; E. M. 1908, Engineering Corps T. & B. V. R. R., Texas. 1910, Topographical and Maintenance engineering work, Denver, Laramie, and Northwestern Kentucky. 1912 Solution-man, Cyanide Mill, Tuscarora Mines Development Co., Tuscarora, Nev. 1912-13, Engineering Department, Empire Zinc Co., Denver, Colo.

Present position: 1913 to date, Resident Engineer and assayer, San Xavier Mine, Ariz., Empire Zinc Co.

James A. Hogle, Salt Lake City, Utah.

Proposed by C. T. Van Winkle, Louis D. Huntoon, Thomas T. Read.

Born, 1876, Salt Lake City, Utah. 1896-99, Yale, Sheffield Scientific School; Ph. B. 1901-02, Columbia (Special Student). 1899-1900, Anaconda Copper Mining Co., Anaconda, Mont. 1901, Boston & Mont. Copper Mining Co., Butte, Mont. Tintio Mining & Development Co., Bingham Canyon, Utah.

Present position: Consulting Engineer.

Leonhard John Hohl, San Francisco, Cal.

Proposed by Robert Schorr, F. W. Bradley, C. H. Munro.

Born, 1863, Switzerland. 1870-74, Public Schools, Vienna, Aust. 1874-77, Realschule Berneck Cta., St. Gall, Switzerland. 1877-80, Technicum, St. Gall. 1880-81, Technicum Wanterthm Cta., Zurich, Switzerland. 1882-91, Penn. R. R., Pittsburg, Pa. 1891-99, Wilkins & Davison, Coal Engrs., Pittsburg, Pa. Oliver Coke Plant, Redstone Jc., Pa. 1900-02, Cherokee Mine, Cherokee, Butte, Co., Cal., Mgr. 1902-06, Cherokee Dredging Co., Oroville, Cal., mgr.

Present position: 1906 to date, Consulting Engr., mostly placer investigations in Western U. S. and Columbia River developments, Brazil.

Percy Edward Holme, El Oro, Mexico.

Proposed by A. F. Main, John McGrath, C. E. Rhodes.

Born, 1880, Leeston Canterbury, N. Z. 1894-96, Boys' High School, Dunedin, N. Z. 1897-99, Otago School of Mines. 1900, Mill foreman, Sons of Gwalia M. Co., Leonora, W. Aust. 1901-02, Mill Supt. 1903, Working underground, Lake View Consols., Kalgoorlie, West Aust. 1904-05, Mill Supt., Morningstar Mg. Co., Southland, N. Z. 1906, Dredging and examination work. 1907-08, Mill Supt., Oxman Prospecting Co., Guazapares, Chihuahua, Mex. 1909, Mgr., Edith Holmes Mining Co., Chihuahua. 1910-11, Mill Supt., The Sierra Mg. Co., Ocampo. 1912, Asst. Supt., Cyanide Plant, El Oro Mining & Ry. Co., El Oro.

Present position: 1913 to date, Asst. Supt., Mill and Cyanide Plant, El Oro Mining & Ry. Co., El Oro.

Ralph Hurd, Swastika, Ont., Canada.

Proposed by W. E. Hurd, M. B. Groover, Sydney Smith.

Born, 1889, Minneapolis, Minn. 1911, Univ. of Penn.; Chemical Engr. 1912, Post-Grad. work, Colo. State School of Mines. 1912-13, Lucky Cross Mines of Swastika, mine surveying and assaying.

Present position: Consulting Engineer.

Kiukich Ishihara, Akita Ken, Japan.

Proposed by T. Wada, B. Katsura, T. Inouye.

Born, ————1897, Mining and Metallurgical Dept. of Kyoto Imperial Univ. 1900, Grad. Kogakushi. 1900-10, Mining Engr. Makinina, Osaruzawa and Ikuno Mine, Mitsubishi Co. 1910, Chief Mining Engr. of Arakawa Mine.

Present position: 1911 to date, Sub. Mgr. Arakawa and Hisanichi Mine.

Kinnosuke Ishiwata, Tagawa-Gori, Busen, Kyushu, Japan.

Proposed by T. Wada, B. Katsura, T. Inouyé.

Born, ————1903, Mining and Metallurgical Dept. Tokyo Imperial Univ. 1906, Grad., Kogokushi. 1906, Mitsu-Bishi Co., Mining Engr.

Present position: Mgr. Kanada Colliery.

Albert C. Jenkins, Seattle, Wash.

Proposed by Joseph Daniels, Milnor Roberts, C. F. Lee.

Born, 1885, Schuyler, Neb. 1906-08, Univ. of Neb. 1911-12, College of Mines of Univ. of Wash.; B. S. 1911, Asst. Engr., coal examination work, Coos Co., Ore. 1912, Engr., placer gold testing, Kenai River, Alaska. 1913, Engr., gold dredging, Magpie Dev. Co., Canyon Ferry, Mont.

Present position: Gold and platinum testing, Princeton, B. C. Mining Engr.

William John Jenkins, St. Louis, Mo.

Proposed by B. F. Bush, P. N. Moore, S. K. Smith.

Born, 1873, Chicago, Ill. City Schools of Chicago. To 1896, General Merchandising, Electric Lighting, Land Investment Co. 1897-1903, Northern Pacific Coal Co. and Northwestern Improvement Co. 1903-12, Western Coal & Mining Co., Gen. Supt., V. P. and Gen. Mgr. and Asst. Fuel Agt., Mo. Pac. Ry.

Present position: 1913 to date, Vice-Pres. and Gen. Mgr., Western Coal & Mining Co. and Consolidated Coal Co. of St. Louis.

Horace A. Johnson, Millers, Nev.

Proposed by A. R. Parsons, W. H. Blackburn, Frederick Bradshaw.

Born, 1885, Hannibal, Mo. 1903-05, Mo. School of Mines, 1907-08, Mo. School of Mines; B. S. 1905-06, Rodman, Cananea Cons. Copper Co. 1906, Transimman, El Paso & Southwestern R. R. 1909-13, Assayer and chemist, Desert Power & Mill Co.

Present position: Mill Foreman, Desert Power & Mill Co.

Percival Johnson, Pulaski, Va.

Proposed by H. L. Haldeman, A. J. Dull, F. E. Cunningham.

Born, 1860, Saltaire, Yorkshire, England. Salt's Technical Schools, Shipley, England, 1884-98, Acct., Secy. and Acting Supt., Dayton Coal & Iron Co., Dayton, Tenn., 1898-1902, Blast-furnace Supt., Va. Iron, Coal & Coke Co., Buena Vista Va. 1902-03, Blast-furnace Supt., Alleghany Ore & Iron Co., Goshen, Va. 1903-04, Blast-furnace Supt., R. Heckscher & Sons Co., Swedeland, Pa. 1905-10, Supt. of Coal Mines, Pulaski Iron Co., Eckman, W. Va. 1911-12, Asst. Sec., Pulaski Iron Co., Philadelphia.

Present position: Gen. Mgr., Pulaski Iron Co., Pulaski, Va.

Carleton Hill Jones, Salt Lake City, Utah.

Proposed by J. C. H. Ferguson, J. Labarthe, A. Frank.

Born, 1884, Sioux Falls, S. D. 1908, Sheffield Scientific School of Yale Univ. B. Ph. 1908-10, Asst. Chemist, Winchester Repeating Arms Co., New Haven, Conn. 1910-12, Supt., Mfg. Dept., Canadian Pacific R. R. Co., Winnipeg, Canada.

Present position: 1912 to date, R. J. Glendinning & Co., Mining and Machinery.

Ichiro Kamimura, Akitaken, Japan.

Proposed by T. Wada, S. Harada, T. Kawamura.

Born, 1885, Yonezawa, Japan. 1903-06, High School, Sendoi. 1906-09, Mining and Metallurgy Section, Technology Dept., Tokyo Imperial Univ.

Present position: 1909 to date, Mining Engr., Osaruzawa Mine, Mitsubishi Co.

Iwaki Kikkawa, Heijo, Chosen, Korea.

Proposed by T. Wada, B. Katsura, T. Inouyé.

Born, 1874, Fukuoka City, Japan. 1896, Mining and Metallurgical Dept., Tokyo Imperial Univ., Tokyo. 1899, Grad. Kogakushi. 1899-1902, Chief Engr., Hokoku Colliery, Fukuoka-Ken, Japan, and Chief Engr., Hoshino Gold Mine, and Sasaguri Colliery. 1903-08, Chief Engr. of Blast-furnace Dept. of Kamaishi Iron Works, Iwaseken, and Chief Engr., Kurihashi Gold Mine.

Present position: Chief Engr. of Government Heijo Coal Mine, Heijo, Korea, and Chief Engr. of the Government Chosen Gold Mines, Chosen.

Arthur Knapp, Ardmore, Pa.

Proposed by A. F. Lucas, W. Clark, W. E. Saunders.

Born, 1885, Round Hill, Conn. 1907, Grad. Cornell Univ. M. E. Course. 1905-06, Instructor in Military Tactics, Captain of Cadets, Cornell Univ. 1907-08, Instructor in Power Engineering and Gas-engine Design, Cornell Univ. 1908-10, Prospect drilling

in Louisiana. 1911, Supt. of Drilling and Production, New Trinidad Lake Petroleum Co., Trinidad, B. W. I. 1912, Supt., Exxes Division of Genl. Petroleum Co., Mid-Wayfield, Cal., drilling, producing, shipping and refining. 1913, Prospect drilling in Louisiana.

Present position: Designing Refining Plants.

George Stuart Krueger, Park City, Utah.

Proposed by F. W. Sherman, James Humes, C. F. Rand.

Born, 1885, Berthoud, Colo. 1891-99, Public Schools, Berthoud, Colo. 1899-1902, High School. 1902-03, State Preparatory School, Boulder, Colo. 1903-07, Colo. School of Mines, Golden, Colo.; E. M. 1909-10, Ellsworth & Klaner Construction Co., mine development and tunnel work, Salt Lake City, and Jarbidge, Nev. Daly-Judge Mining Co. Supt. of Ont. Silver Mine, Crowther Leasing Co., Salt Lake City.

Present position: 1911 to date, Daly-Judge Mining Co., Mine Boss, Mine Foreman, Supt. of Mines.

Henry Lang, Montclair, N. J.

Proposed by W. L. Saunders, G. A. Howells, R. S. Carter.

Born, 1864, Martinsburg, W. Va. Public and Private Schools. General experience in business for thirty years.

Present position: Director, Ingersoll-Rand Co. President Southport Mining Co., Salt Lake City, Utah. President, Rendrock Powder Co., New York.

Marcus L. Latham, Melones, Calaveras Co., Cal.

Proposed by E. H. Simonds, J. A. Fulton, W. G. Devereux.

Born, 1878, Garrettsville, Ohio. 1894-95, Grand Island College, Grand Island, Neb. 1902, Special work in assaying and cyanidation, San Francisco, Cal. 1897-1901, DeLamar Mining Co., DeLamar, Idaho. 1903-05, Scales & Smith, DeLamar, Idaho, Supt. of Cyanide Plant.

Present position: 1911 to date, Reconstructing and operating mill for reducing pyritic concentrates by cyanidation, Melones, Cal. Member of the firm of Simonds & Latham.

Andrew C. Lawson, Berkeley, Cal.

Proposed by J. W. Finch, D. W. Brunton, T. B. Stearns.

Born, 1861, Scotland. 1883, A. B., Toronto. 1885, A. M., Toronto. 1888, Ph. D., Johns Hopkins. 1882-90, Geologist, Geol. Survey of Canada.

Present position: 1890 to date, Professor of Geology, Univ. of Cal.

Clinton R. Lewis, Dawson, Yukon Territory.

Proposed by M. Roberts, J. Daniels, C. F. Lee.

Born, 1890, Minneapolis, Minn. 1912, Univ. of Wash.; B. S., Kenai Alaska Gold Co., Seward, Alaska, Assayer and Engr. 1913, Alaska Treadwell Gold Min. Co., Treadwell, Alaska, Cyanide Plant.

Present position: 1913 to date, Canadian Klondike Mining Co., Dawson, Y. T.

Harrison Olney Lewis, Fort Smith, Ark.

Proposed by F. Bache, H. Denman, E. McAuliffe.

Born, 1876, Blossburg, Pa. High School, Phillipsburg, Pa. 1898-1900, Cambria Steel Co., Mining Dept. 1900-02, City of Johnstown, Pa., Engineering Dept. 1902-03, Webster Coal & Coke Co., Asst. Mining Engr. 1903-05, Mining Engr., Supt., Derry Coal & Coke Co., Pennsylvania.

Present position: 1906 to date, Engineer, Bache, Denman Coal Co., Fort Smith, Ark.

Douglas Clermont Livingston, Moscow, Idaho.

Proposed by L. K. Armstrong, J. C. Haas, E. P. Spalding.

Born, 1877, London, England. 1886-92, Public School, Forest School, Essex, Eng. 1906, B. Sc., McGill Univ., Montreal, Canada. 1905, Special student in Metallurgy, Stanford Univ., Cal. 1898-1902, Tyee Copper Co. 1906-08, Tigre Mining Co., Sonora, Mexico. 1908-10, Supt. North Tigre Co., Sonora, Mexico, and Fortuna Co. 1910-11, Private consulting and engineering work, Douglas, Ariz. 1911, Engr., Moctezuma Copper Co.

Present position: 1911 to date, Professor of Mining Eng., Univ. of Idaho. At present head of the mining dept.

John M. Longyear, Fisher Hill, Brookline, Mass.

Proposed by A. C. Lane, R. H. Richards, A. H. Eustis.

Born, 1850, Lansing, Mich. 1862-63, Prep. Dept., Olivet College, Mich. 1864-65, Prep. Dept., Georgetown College, D. C. 1873-1914, Exploring, directing exploratory work, financing exploring and mining in the iron districts of Lake Superior, Menominee, Crystal Falls, Gogebie, and Mesaba.

Present position: 1913 to date, Exploring, financing and mining coal on Spitsbergen. Owner and Mgr. of mineral and timber lands.

Archibald Kennedy Macfarlane, Parral, Chihuahua, Mexico.

Proposed by G. Cartani, W. S. Harrison, John H. Allen.

Born, 1876, Scotland. 1885, General education in Edinburgh, Scotland. 1885-1900, Continuation Classes Glasgow and West of Scotland Technical College. Apprentice engineer, Drousmuir & Jackson, Ltd., Govan, Glasgow. 1900-01, Fraser & Chalmers, Ltd., Kent. 1902-06, Grad. as surveyor and mining engineer, Freiberg Bergakademie, Saxony, Germany. 1907, Asst. and Mgr. Premier Development Co., Ltd., of Mexico, Chihuahua, Mexico. 1907-08, Mill engineer, San Francisco del Oro Mining Co., Ltd., Parral, Mexico. 1908-10, Asst. Mgr. and Mgr., Manta Mining Co., Ltd., Santa Eulalia, Chihuahua, Mexico. 1910-11, engaged on Alaskan Expedition.

Present position: 1911 to date, Mill Mgr. and Asst. and Gen. Mgr., San Francisco Mines of Mexico, Ltd., Parral, Chihuahua, Mexico.

Benjamin Magnus, Mount Morgan, Queensland, Australia.

Proposed by E. P. Mathewson, Robert Sticht, Frederick Laist.

Born, 1878, New York City. 1886-92, N. Y. Public Schools. 1893-96, College of the City of New York. 1896-1900, Columbia Univ. School of Engineers; E. E. 1900, Raritan Copper Works, Perth Amboy, N. J. 1900-03, Anaconda Copper Mining Co., Montana. 1903-06, Calumet & Hecla Mining Co., Buffalo, N. Y. 1906-07, Mountain Copper Co., Martinez, Cal. 1907-12, Gen. Mgr. Electrolytic Refining & Smelting Co. of Aust., Port Kembla, N. S. W.

Present position: 1912 to date, Consulting Engineer to Electrolytic Refining & Smelting Co. of Aust. and Genl. Mgr. Mount Morgan Gold Mining Co., Ltd.

Van H. Manning, Washington, D. C.

Proposed by J. A. Holmes, C. F. Rand, G. O. Smith.

Born, 1861, Horn Lake Depot, Miss. 1879, Junior year, Univ. of Mississippi. 1886-1910, U. S. Geological Survey as topographer. 1910-14, Asst. to the Director, U. S. Bureau of Mines, Washington, D. C.

Present position: Asst. Director, U. S. Bureau of Mines.

Percy Edward Marmion, London, E. C., England.

Proposed by W. J. Loring, R. G. Brown, T. A. Rickard.

Born, 1880, Western Australia. High School, Perth, W. A. Fremantle Grammar School, W. A. 1896, Riverview College, Sydney, N. S. W. 1898, School of Mines, Ballarat, Victoria; A. S. M. B. 1900, Mill at Lake View, So. Gold Mining Co., Ltd. 1900-01, Assayer and surveyor, Red Hill Gold Mines, Ltd. 1901-05, Chemist, Metallurgist, Asst. and acting Gen. Mgr., Westralia Mt. Morgan Gold Mines Co., Ltd. 1905-06, Gen. Mgr., Princess Alix Gold Mining Co., Ltd., W. A. 1906, Chief Asst. at Great Cobar Copper Mines, N. S. W. 1907-09, Gen. Mgr. and attorney, Cowley Copper & Development Syndicate, Ltd. 1910-12, Chief Asst., C. M. Rolker, London.

Present position: 1913 to date, engineer with Bewick Moreing & Co., London.

James J. McLellan, Webb City, Mo.

Proposed by H. B. Pulsifer, E. E. R. Tratman, F. T. Snyder.

Born, 1872, Louisville, Ky. 1895-99, Rose Polytechnic Inst., Terre Haute, Ind.; B. S. 1899 to date, operating various zinc and lead mines in Southwest Mississippi. Formerly supt. at Continental Mine, Maple Leaf, and Mary C. Built and operated plant of the Mammoth Lead and Zinc Works.

Present position: Charge of Electrical Z. & L. Mining Co.'s plant near Webb City, Mo.

Russel H. McMillen, Aspinwall, Pa.

Proposed by S. L. Goodale, H. C. Ray, H. B. Meller.

Born, 1878, Masontown, W. Va. 1904, Grad. W. Va. Univ.; A. B. 1904-07, Chemist, Research Dept., Westinghouse Electric & Mfg. Co., East Pittsburg, Pa. 1907-09, Works Mgr., American Vanadium Co., Bridgeville, Pa.

Present position: 1910 to date, Chief Chemist, Crescent Works, Crucible Steel Co., of America, Pittsburg, Pa.

Joseph Edwin Miller, Lewistown, Mont.

Proposed by W. A. Young, D. C. Bard, C. H. Bowman.

Born, 1885, Dubuque, Iowa. 1902-06, Dubuque High School. 1906-08, Ohio State Univ., Columbus, O. 1908-10, Mich. College of Mines, Houghton, Mich.; B. S., E. M. 1910, Big Four Lead Mining Co., Dubuque, Iowa. 1912, Phelin Gold Mining Co., New Year, Mont.

Present position: 1913 to date, County Surveyor, Fergus Co., Mont.

Harry William Montz, Wilkes-Barre, Pa.

Proposed by Douglas Bunting, Charles Enzian, J. M. Humphrey.

Born, 1885, Lehigh, Pa. 1907, Grad. Pa. State College, Min. Engr.; B. S. 1907, H. C. Frick Coke Co., Uniontown, Pa. 1908, D. & H. Coal Co., Scranton, Pa. 1908-09, Kingston Coal Co., Kingston. 1909, Lehigh Valley Coal Co., Wilkes-Barre, Pa.

Present position: Dir. Engr., Wyo. Div.

Lawrence Irving Neale, New York, N. Y.

Proposed by H. L. Smyth, C. H. White, W. S. Weeks.

Born, 1885, Boston, Mass. 1897-1902, Shady Side Academy, Pittsburg, Pa., Scientific Dept. 1902-06, Harvard Univ.; A. B. 1906-08, George A. Fuller Co., Building construction, N. Y. Member of American Soc. for Testing Materials, International Soc. for Testing Materials, National Fire Protection Asso., Harvard Engineering Soc. of N. Y., Asso. of Harvard Engr.

Present position: In charge of tests for J. B. King & Co.

Christopher Walter Nelson, Reno, Nev.

Proposed by P. Kirkegaard, J. W. Astley, O. N. Scott.

Born, 1870, Copenhagen, Denmark. Grad. of Winding and Hammer High School, Copenhagen, Denmark. 1894-96, Student Land Surveying under J. Ogilvie, O. L. S., Ont., Canada. 1896-98, Prospecting for minerals in Rainy River region, Canada. 1898-99, Employed on magnetic surveys in Canada. 1899-1900, Employed by the American Wire & Steel Co. on the Atikokan Iron Range; Asst. to supt. 1900-10, Prospecting in Canada. 1910-12, Supt., North Dome Mine, Porcupine, Ont., Canada.

Present position: Supt. and part owner of Granite Hill Copper Mine, Plumas County, Nev.

Francis Clement Newton, Perth Amboy, N. J.

Proposed by C. P. Linville, R. H. Lee, B. E. McKechnie.

Born, 1874, Washington, D. C. 1890-91, Corcoran Scientific School, Columbia Univ. 1891-93, Johns Hopkins Univ., Dept. of Chemistry. 1894-98, Asst. Assayer, U. S. Assay Office, Boise, Idaho. 1898-1905, Chief Assayer, U. S. Assay Office, Seattle, Wash. 1905-07, Chief Chemist, Selby Smelting & Lead Co., Selby, Cal. 1907-12, Asst. Supt., Selby Smelting & Lead Co.

Present position: 1912 to date, Supt. American Smelting & Refining Co., Perth Amboy, N. J.

Takichi Ohashi, Kumamoto High Technical School, Kumamoto, Japan.

Proposed by T. Wada, B. Katsura, T. Inouyé.

Born, —, Kagoshima City. 1900 Mining and Metallurgical Dept., Tokio Imperial Univ., Tokio, Japan. 1903, Grad. Kogakushi. Post Grad. Course. 1904, Government engineer of Bureau of Mines, Agricultural and Commercial Dept. 1906, Professor of Mining, Kumamoto High Technical School, Kumamoto, Japan, study of mining abroad. 1906-09, Studied in Berg Akademie in Freiberg, Saxony, and other German schools, traveled throughout Europe and America..

Present position: Professor of Mining, Kumamoto High Technical School, Kumamoto, Japan.

Chester Andrew Orr, Cleveland, Ohio.

Proposed by S. D. Quarrie, B. G. Klugh, T. T. Read.

Born, 1882, Syracuse, N. Y. 1901, Grad. Willoughby, Ohio, High School. 1901-05, Case School of Applied Science, Cleveland, Ohio; B. S. 1905-06, Chemist, Diamond Metal Co. 1906, Chief Chemist, Toledo Furnace Co. 1906-07, Engineer and salesman, Arctic Ice Mch. Co. 1907-09, Asst. Supt. Central Furnaces. 1909-10 Supt. "E" Fce., Amer. Steel & Wire Co.

Present position: Supt. Central Furnaces, American Steel & Wire Co., Cleveland, Ohio.

James Heber Parker, Reading, Pa.

Proposed by R. E. Jennings, W. B. Kunhardt, J. S. Pendleton.

Born, 1881, Reading, Pa. 1896, Grad. Reading High School. 1902, Grad. Philadelphia College of Pharmacy; P. D. 1905, Grad. Cornell Univ.; A. B.

Present position: 1905 to date, Asst. Chemist, Foreman in charge of Crucible Dept., Asst. Supt., Metallurgist, Carpenter Steel Co.

Ralph Eugene Henry Pomeroy, McGill, Nev.

Proposed by C. B. Lakenan, A. B. Colwell, F. W. Millard.

Born, 1881, Chicago, Ill. 1902-05, Mich. College of Mines; E. M. 1900-02, Chicago Copper Ref. Co., Blue Island, Ill. 1905, Kansas City Cons. Smelting & Refining Co., El Paso, Tex. 1905-06, American Smelting & Ref. Co., Monterey, Mexico, 1906, American Smelters Sec. Co., Velardena, Mexico. 1906-08, American Smelting & Ref. Co., Aguascalientes, Mexico. 1908, Copper Queen Cons. Copper Co., Bisbee, Ariz.

Present position: Acting Smelter Supt., Steptoe Valley Smelting & Mining Co., McGill, Nev.

Edwin Leight Porch, Jr., San Antonio, Texas.

Proposed by W. B. Phillips, A. F. Lucas, W. H. Hackett.

Born, 1889, Kissimmee, Fla. 1906, Grad. Ball High School, Galveston, Tex. 1906-07, Univ. of Texas, Austin, Tex. 1908-11, Mich. College of Mines; B. S., E. M. 1912-13, Univ. of Texas, special student in Electricity and Technology of Fuels. 1911, Timberman and stemmer, Calumet & Hecla Mine, Calumet, Mich. 1911-12, Engineer and zinc room man, cyanide mill, Espoda Mines Co., Hostotipaquillo, Jalisco, Mexico.

Present position: Temporarily employed in City Assessor's Office, San Antonio, Texas.

Jose Portuondo, Santiago de Cuba.

Proposed by G. W. Pfeiffer, Pedro Aguilera, C. F. Rand.

Born, 1868, Santiago de Cuba. 1875-77, Private school in Santiago de Cuba. 1878-81, Boarding school in Barcelona, Spain. 1882-85, Boarding school in New York. 1886, College of Pharmacy of N. Y. 1887, Private school in N. Y. 1888-90, School of Mines of Columbia Univ., C. E. 1893, Geological Survey, State of N. Y. 1895, Northern R. R., Guatemala, C. A. 1896-98, War of Independence of Cuba. 1899, Dept. of Public Works, Havana. 1900-09, Chief of the Forestry Dept. in the Province of Oriente, Cuba.

Present position: Engineer in the Mining and Forestry Dept., Oriente, Cuba.

Frank Remington Pretzman, New York, N. Y.

Proposed by J. F. Kemp, Max Roesler, W. J. Millard.

Born, 1890, Chicago, Ill. 1905-08, General education at Marlborough College, Wiltshire, England. 1908-10 and 1912-13, Technical at the Royal School of Mines, So. Kensington, London. 1913, A. R. S. M., Royal School of Mines. 1913, Fellow of the Geological Soc. of London. 1910-11, Mazapil Copper Co. of Zacatecas, Mexico, Surveyor. 1911-12, Foundation Co. of N. Y. at St. Albert, Alta., Can.

Present position: Post Grad. Course at Columbia Univ.

William Reed, El Oro, Mexico.

Proposed by A. F. Main, J. McGrath, C. E. Rhodes.

Born, 1886, Loughton, England. 1897-1900, Wanstead School, Essex, East London College (London Univ.), for chemistry, metallurgy, etc. 1900, Laboratory apprentice at Locke, Lancaster and W., W. & R. Johnson & Sons, Ltd., Limehouse, London. 1904-06, Works Foreman of Smelting and Refining. 1906-10, Asst. Mgr. 1910-13, Works Mgr.

Present position: 1913 to date, El Oro Mining & Ry. Co., Mexico, Zinc Room Foreman.

William C. Reilly, Youngstown, Ohio.

Proposed by C. S. Robinson, H. S. Brame, E. T. McCleary.

Born, 1868, Youngstown, O. Grammar School. 1882-87, Brown-Bonnell Iron Co. in Blast Furnace and Rolling Mill Statistical Work. 1888-99, Mahoning Valley Iron Co., Cost Accounting and Auditor. 1899-1900, Republic Iron & Steel Co., Asst. to the District Mgr. of the Mahoning and Shenango Valley District.

Present position: 1900 to date, Youngstown Sheet & Tube Co., as Auditor, Gen. Supt., Operating Dept., both mechanical and metallurgical.

Charles A. Reno, Manitou, Colo.

Proposed by W. R. Chedsey, H. J. Wolf, F. W. Traphagen.

Born, 1873, Carnegie, Pa. 1908, Colo. School of Mines; E. M. 1909-11, Pioneer Cons. Mines Co., Sampler and Assayer. 1911-13, Working a 10 stamp mill, Cosala, Mexico. 1913, La Luz & Los Angeles M. & M. Co., Nicaragua, C. A.

Present position: Prospecting in Colombia, S. A.

Luther V. Rice, Chicago, Ill.

Proposed by C. W. Gennet, Jr., G. M. Davidson, F. K. Copeland.

Born, 1865, Ladoga, Ind. Common Schools, Indiana. Central Indiana Normal School. 1889, Cornell Univ., Ithaca. 1890-91, Asst. Engr., Central Bridge, Cincinnati, Ohio. 1891-92, Asst. Engr., P. & L. E. R. R. 1892, Res. Engr., Union Station, St. Louis, Mo. 1893, Cons. Engr., Ferris Wheel, Chicago. 1894-97, Cons. Engr. and Mgr. 1898-99, Res. Engr., Cement Plant, Fenton, Mich. 1900-03, Designing and Cons. Engr., Ziegler Coal Co.

Present position: 1903 to date, Civil and Mining Engr., Robert W. Hunt & Co., and Mgr. Field Mining & Milling Co.

Fred Edward Riede, Austinville, Va.

Proposed by F. L. Nason, W. O. Borchardt, C. F. Rand.

Born, 1886, Canon City, Colo. 1901-04, Canon City High School. 1906-10, Mo. School of Mines, Univ. of Mo.; B. S. 1910-11, Asst. in Research Dept., N. J. Zinc Co. (of Pa.), Palmerton, Pa. 1911-12, Asst. in Oxide Dept., N. J. Zinc Co., Palmerton, Pa.

Present position: Bertha Mineral Co., Austinville, Va., Asst. to Supt., now Supt.

Jasper Thistle Robertson, Goldfield, Colo.

Proposed by J. T. Milliken, D. W. Brunton, J. W. Finch.

Born, 1887, Tillicoultry, Scotland. 1894-1902, Chicago Public Schools. 1902-06, R. T. Crane Manual Training High School, Chicago. 1906-09, Mich. College of Mines, Houghton, Mich.; B. S., E. M. 1909-10, Golden Cycle Mine, Cripple, Colo., and Golden Cycle Mill, Colo. Springs, Colo. 1910-11, Mining Engr., Alaska Cons. Mines Co., Juneau, Alaska. 1911-12, Mining Engr., Golden Cycle Mining Co., Cripple Creek, Colo. 1912-13, Examining Mines in Canada.

Present position: 1913 to date, Asst. Supt., Golden Cycle Mining Co., Cripple Creek, Colo., now Supt.

Sansom M. Rodgers, Pittsburg, Pa.

Proposed by J. S. Unger, H. P. Tiemann, C. F. W. Rys.

Born, 1860, Brook Co., W. Va. 1883, Bethany College, W. Va. 1885, Mich. Univ., special course in chemistry and physics. 1892, Chief chemist, Hainsworth Steel Co., Pittsburg, Pa., Newburg Steel Works, A. S. & W. Co., Cleveland, Ohio, Supt. O. H. Dept. at Worchester, Genl. Supt. North Works mill.

Present position: Metallurgist to the A. S. & W. Co.

George Richard Rogers, Gowganda, Ont., Canada.

Proposed by G. M. Colvocoresses, W. G. Miller, A. A. Cole.

Born, 1877, Teuterville, N. S. W., Aust. 1889-92, Grammar School. 1893-97, Rivertree Silver Mines, Ltd., N. S. W., Aust., as Assayer's Asst. 1897-99, Studied mining, engineering and surveying. 1900-01, Brisbane Technical College. 1901-02, Ballarat School of Mines. 1893-94, Big Hill Gold Mines, charge of mill and cyanide plant, Falgia, Queensland, Aust. 1904, Left for South Africa, three years' experience on W. Coast. 1908, Charge of Alpine Gold Mine, Ltd., Eastern Ontario.

Present position: Mgr. Mann Mines, Ltd., Gowganda, Ont., Canada.

Charles Clemons Rose, Scranton, Pa.

Proposed by I. A. Stearns, Douglas Bunting, R. V. Norris.

Born, 1847, Rose Point. Sellecks Select School, Norwalk, Conn. 1871, Levelman, N. Y. & Albany R. R. location. 1872, Asst. Engr., N. Y. & Canada R. R. 1877, Surveys, Staten Island. 1880, N. Y., Lack. & Western Ry., Asst. Engr. Construction. 1882, Div. Engr. 1883-95, Div. Engr., D. L. & W. R. R.

Present position: 1895 to date, Supt. Coal Dept., D. & H. Co., Scranton, Pa.

Richard Alexander Ruff, Elkhorn, W. Va.

Proposed by J. J. Lincoln, C. E. Krebs, G. S. Borden.

Born, 1881, Longwood, Va. 1903, B. S., Washington and Lee Univ. 1903-05, Clark & Krebs, civil and mining engineers, Kanawha Falls, W. Va. 1905-10, New River Fuel Co., Fayette and Raleigh Counties, W. Va., as division engineer. 1911, Clinchfield Coal Corp., Dante, Va., mining engineer.

Present position: 1912 to date, Mining Engineer, Crozer Land Association, Elkhorn, W. Va.

Edwin Grey Rust, Sewickley, Pa.

Proposed by C. S. Robinson, H. S. Braman, E. T. McCleary.

Born, 1870, Leesburg, Va. Common School, Kenyon Military Academy, Technical course Lehigh Univ., Apprenticeship Machine Shop, Maryland Steel Co. 1894, Machinist and draftsman, Southwark Foundry & Machinery Co. 1896, Master Mechanic, Lack. Steel Co. 1899, Master Mechanic and Chief Engr., Colo. Fuel & Iron Co. 1903-07, V. P. & Gen. Mgr. Elk Rapids Iron Co. 1908-12, Pres. and Gen. Mgr., Sheffield Coal & Iron Co.

Present position: Dept. Supt., Jones & Loughlin Steel Co.

Henry Bedinger Rust, Pittsburg, Pa.

Proposed by C. S. Robinson, E. T. McCleary, H. S. Braman.

Born, 1872, Leesburg, Va. Common school education, going to work on an engineering corps at seventeen. 1890-94, Various positions on engineering corps. 1894-1901, Asst. City Engr., Pittsburg, Pa., charge of designing and constructing Schenley Park and other work. 1901-03, Supt. of Construction, Colo. Fuel & Iron Co. Charge of erection of improvements at Minnequa Steel Works, including four blast furnaces, rail mill, Bessemer, sewage system, water system, shops, etc. 1903-09, Vice-President and Gen. Mgr., Rust Boiler Co.

Present position: 1909 to date, Special Representative for Babcock & Wilcox Co.

Thomas J. Ryan, New York, N. Y.

Proposed by F. L. Hess, D. T. Day, E. W. Parker.

Jacob E. Rypinski, San Mateo, Costa Rica, C. A.

Proposed by P. G. Spilsbury, Robert Peele, E. L. Kurtz.

Born, 1888, Bryan, Texas. Graded school, Bryan, Texas. 1902-06, Grad. De Witt Clinton H. S., N. Y. 1906-10, Grad. Columbia School of Mines, E. M. 1910, Candor Mines Co., Candor, N. C., Surveyor. 1910-11, Practical mining and milling, Bingham, New Haven Mining Co., Bingham Canyon, Utah. 1912-13, Asst. Engr., St. Lawrence Pyrites Co., De Kalb Junction, N. Y.

Present position: 1913 to date, Engr. Aguacate Mines Co., San Mateo, Costa Rica, C. A.

Reno 'de Sallier du Pin, New York, N. Y.

Proposed by Robert Linton, R. M. Atwater, Jr., C. G. Atwater.

Born, 1881, Cape Vincent, N. Y. Collegiate School, New York, N. Y. 1901-05, School of Mines, Columbia University; E. M. 1905-06, Chief Assistant to R. M. Atwater, Jr. 1906-1911, Member firm of Atwater, Linton & Atwater.

Present position: General mining engineering practice.

Cyril Charles Sanders, New York, N. Y.

Proposed by W. McA. Johnson, C. A. H. de Saulles. (One signature required.)

Born, 1881, Elizabeth, N. J. 1899, Montclair High School. 1903, Sheffield Scientific School of Yale Univ.; Ph. B. 1903-04, Assayer, Empress Josephine Mining Co., Bonanza, Colo. 1904-05, Lanyon Zinc Co., Denver, Colo. 1905-14, Metallurgist, Sanders Ore Separating Co., Marion, Ky. 1907-08, Metallurgist, Tri Billion Co., Kelly, N. M. 1909-11, Mgr., Cascade Gold Mining & Milling Co., Marysville, Utah. 1912-13, Mining Engr., Picher Lead Co., Joplin, Mo.

Present position: Engr., Sanders Ore Separating Co., organizing consolidation in Marysville, Utah.

Carl F. Schaber, Bessemer, Ala.

Proposed by C. T. Fairbairn, W. J. Penhallegon, G. G. Dobbs.

Born, 1886, Jackson, Mich. 1907, Jackson High School. 1907-08, Purdue Univ. 1909-12, Mich. College of Mines, 1911, Timberman, Tobin Mine, Crystal Falls, Mich. 1911, Asst. Engr., Breitung Kaufman Interests, Negaunee, Mich. 1912, Asst. Engr., Copper Range Cons., Painesdale, Mich., Transitman, Location & Construction Co. M. & St. R. R., Aberdeen, S. D.

Present position: 1912 to date, Asst. Engr., Republic Iron & Steel Co., Bessemer, Ala.

Oscar T. Schinbeckler, Unsan, Chosen, Korea.

Proposed by J. B. Lower, Alf Welhaven, J. A. Vernon.

Born, 1876, Whitley Co., Ind. Common Schools. 1893-96, Val. Univ., Valparaiso, Ind. 1896-99, Common School Teacher. 1899-1902, Dep. & Co. Surveyor, Whitley Co., Ind. 1902-03, Bank Clerk, Prov. Trust Co., Col. City, Ind. 1903-04, Rodman, Pa. P. R. Co.

Present position: 1904 to date, Oriental Consolidated Mining Co., Unsan, Korea, now Mine Sampler and Mine Surveyor.

Samuel A. Scott, Macdonald, W. Va.

Proposed by P. C. Thomas, Thomas Nichol, G. W. Engel.

Born, 1871, Elizabeth, Pa. 1893, Grad. Ohio Northern Univ. 1894-96, Asst. Engr., Loyal Hanna Coal & Coke Co. 1897-99, Gen. engineering work, located at Duquesne, Pa. 1899-1911, Monongahela River Cons. Coal & Coke Co. of Pittsburg, Division Engr. Asst. Chief Engr., Chief Engr., Asst. Gen. Mgr. and Gen. Mgr. mines. Present position: 1912 to date, Gen. Mgr., New River Co., Macdonald, W. Va.

Joseph P. Stampher, Wharton, N. J.

Proposed by Felix Cremer, R. W. Raymond, Joseph Struthers.

Born, 1870, Portland, Ore. Public School. 1894, Underground Supt., F. L. Barlie, Columbia Mine, Sumpter, Ore. 1910, Foreman, Mohawk and Combination Mine for Goldfield Con. Co.

Present position: Mine captain, Empire Steel & Iron Co., Ltd., Mt. Hope, N. J.

Harold W. Stotesbury, Tonopah, Nev.

Proposed by J. E. Suprr, W. H. Blackburn, W. H. Sirdevan.

Born, 1883, Buffalo, N. Y. 1902, High School, Leadville, Colo. 1902-07, E. M. Colo. School of Mines, Golden, Colo.

Present position: 1907 to date, Tonopah Mining Co. of Nev.

Albert G. Suydam, Lark, Utah.

Proposed by A. Frank, R. C. Gemmell, C. W. Whitley.

Born, 1883, Denver, Colo. 1889-99, Public Schools, Denver and New York. 1899-1902, Preparatory school, Keystone Academy, Factoryville, Pa. 1902, Columbia Univ. 1906, School of Mines; E. M. 1906-07, Assayer and Engr., Jumulco Copper Co., and Asst. Supt., Continental Mining Co., Coah., Mexico. 1907-08, Examination in U. S. and Mex. for Lanyon Zinc Co. 1908-09, Supt., San Roberto and San Bernebe Mines, Cape Copper Co., Zac., Mexico, Examination work at Pachuca, Hid., with F. W. Roger and elsewhere with J. O. Helm., Supt. Revenue Mont. Mine and Gen. Supt. Revenue I. M. Co.

Present position: Metallurgist, Ohio Copper Mining Co.

Wallace North Tanner, Anaconda, Mont.

Proposed by E. P. Mathewson, C. D. Demond, F. F. Frick.

Born, 1873, Minneapolis, Minn. Common and High Schools, Minneapolis. 1896, Grad. Univ. of Minn.; M. E. Draftsman, Boston & Mont. Co., Great Falls, Mont. 1897-99, Boston & Mont. Co., Butte. 1899-1904, Anaconda Copper Mining Co., Anaconda, Draftsman and chief draftsman. 1904-06, Engr. Mining Dept., Allis Chalmers Co., Chicago. 1906-08, Consulting Engr., Salt Lake City. 1908-09, Concrete work, St. Paul. 1909-14, Supt. Anaconda Copper Mining Cos. Foundry.

Present position: Chief Engr., Anaconda Copper Mining Co., Reduction Dept.

Warner G. Taylor, Stanhope, N. J.

Proposed by J. S. Kennedy, F. L. Grammer, J. E. Johnson, Jr.

Torsten Anderson Tesch, Oxelosund, Sweden.

Proposed by G. K. Hamfeldt, J. O. E. Trots, P. T. Berg.

Born, 1879, Boxholm, Sweden. 1900, Grad. Royal Technical High School, Stockholm, Sweden. Mech., Mining and Metallurgical Engr. 1901-03, Draftsman, Carnegie Steel Co. Carrie F'ces, Rankin, Pa. 1903-04, Draftsman, Carnegie Steel Co., Homestead, Pa. 1904-05, Chief Draftsman, Algoma Steel Co., Sault Sainte Marie, Ont., Canada. 1905-07, Chief Draftsman, Midland Steel Co., Midland, Pa. 1907-08, Constructing Engr., Birmingham Coal & Iron Co., Birmingham, Ala. 1908-11, Chief Draftsman, de Wendel et Cie., Hayingen, Lorraine, Germany. 1911-13, Travel and studies in metallurgy and mining in Sweden, Germany, France, Spain, etc., preparing reports on same.

Present position: 1913 to date, Chief Draftsman, Oxelosunds Jadwerksaktiebolag, Oxelosund, Sweden.

Herbert George Thomson, Dedrick, Trinity Co., Cal.

Proposed by H. A. Morrison, S. B. Cristy, E. B. Durham.

Born, 1888, Oakland, Cal. 1907-11, College of Mining, Univ. of Cal.; B. S. 1911-13, Filterman, Solutionman, Goldfield Con. Mill. 1913, Solutionman, Black Oak Mill, Black Oak Dev. Co., Soulsbyville, Cal.

Present position: 1913 to date, Construction work on new mill, solutionman, Globe Con. Mill, Globe Con. Mining Co.

Oscar Russell Turner, Park City, Utah.

Proposed by J. Humes, F. W. Sherman, C. F. Rand.

Born, 1892, St. Paul, Minn. 1900-10, Preparatory schools in various parts of the U. S. 1910-13, Sheffield Scientific School of Yale Univ.; Ph.B. 1909, Summer, Sampled Ray Central Mine of Ray, Ariz. 1910, Summer, Surveyed and tested methods of saving black sand in a placer mine in Waldo, Ore.

Present position: 1913 to date, Engr., Silver King Coalition Mines Co., Park City, Utah.

Kageaki Uyeno, Tokyo, Japan.

Proposed by T. Wada, B. Katsura, T. Inouyé.

Born, ———. 1901, Mining and Metallurgical Dept., Tokyo Imperial Univ., Tokyo, Japan. 1904, Grad. Kogakushi, Engr. of Government Bureau of Mines, Osaka Office. 1913, Retired from office.

Present position: Private.

George Fulton Waddell, Salt Lake City, Utah.

Proposed by A. Frank, R. C. Gemmell, E. W. Whitley.

Born, 1865, Stewiacke, Nova Scotia. Public School. 1882-86, Machinist apprentice work with Rodney Hunt Mch. Co., Orange, Mass. 1886-90, Machinist, American Tool & Mch. Co., Hyde Park, Mass. 1890-1903, Tool Maker, Draftsman, Foreman, Supt. of Shops, Mgr. of Mining, Mchy., and Supply Store, Testing Fuel and Steam Plants, Mech. Supt., Anaconda Copper Mining Co., Butte and Anaconda, Mont. 1903-05, Engineering and Sales Depts., Power & Mining Mchy. Co., Cudahy, Wis. 1905-07, Mill Supt., Copperton Plant of Utah Copper Co., Salt Lake City, Utah. 1907-13, Mill Supt., Steptoe Valley Smelting & Mining Co., McGill, Nev.

Present position: Gen. Mgr., Ohio Copper Mining Co., Salt Lake City, Utah.

William John Wallace, Chihuahua, Mexico.

Proposed by J. F. Orr, W. N. Fink, A. C. Brinker.

Born, 1883, Clarksburg, Mich. 1902, Houghton, Mich., High School. 1905, Mich. College of Mines; E. M. 1905, With Mr. Clausen, City Engr., Houghton, Mich. Engr., Tombstone Cons. Mines, Tombstone, Ariz. 1906, Engr. with H. A. Allen, Cons. Engr., Chicago. 1909, Supt., Bunker Hill Mines, Tombstone, Ariz. 1910, Engr. with H. L. Hollis, Chicago. 1911, Supt., Princessa Mine, Cusi, Chihuahua.

Present position: 1913 to date, Supt., Cusi Mining Co., Cusi, Chihuahua, Mexico.

Charles Kenneth White, Treadwell, Alaska.

Proposed by R. A. Kinsie, W. P. Lass, R. G. Wayland.

Born, 1889, Sioux City, Iowa. Till 1902, Grammar School, Sioux City, Iowa. 1902-07, High School, Sioux City, Iowa. 1908-13, Univ. of Cal.; B. S. 1907, Ariz. Exploration Co., Mayer, Ariz. 1908, North Star Mines Co., Grass Valley, Cal. 1910-11, Yukon Gold Co., Dawson, Y. T., Canada. 1912, Tonopah Extension Mining Co., Tonopah, Nev. Mont. Tonopah Mining Co., Tonopah, Nev. 1912-13, Spencer C. Browne, San Francisco, Cal. 1913, Jualin Alaska Mines Co., Jualin, Alaska.

Present position: 1913 to date, Alaska Juneau Gold Mining Co., Treadwell, Alaska, Surveyor.

Harold Whittingham, Iglesias, Sardinia, Italy.

Proposed by C. W. Wright, R. E. Hore, R. B. Watson.

Born, 1884, Market Rasen, England. 1891-95, Elementary. 1895-1901, De Aston School, Market Rasen, England. 1909-12, Mich. College of Mines, Houghton, Mich.; B. S., E. M. 1906-09, Nipissing Mining Co., Ltd., Cobalt, Ont., rodman, surface transitman, chief transitman (underground), prospector. 1912-13, American Smelting & Refining Co.

Present position: 1913 to date, Engr. Societ  di Pertusola Iglesias, Sardinia, Italy.

Gordon Howard Wilcox, Kyle, McDowell Co., W. Va.

Proposed by L. E. Tierney, J. J. Lincoln, J. S. Shaw.

Born, 1865, Llewellyn, Pa. 1871-78, Public School, Llewellyn, Pa. 1878-81, High School, Minersville, Pa. 1881-83, High School, Pottsville, Pa. 1885-88, U. S. R. M. School, S. P. Chase at New Bedford, Mass. 1881-83, Chairman on Engr. Corps, Shamokin, Pa., Phila. & Reading Coal & Iron Co. 1885-1900, Engr. Corps at Tremont, Pa. 1900-06, Chief Engr., Shamokin, Pa., Mineral Railroad & Mining Co.

Present position: 1906 to date, Mining Engr., Powhatan, Lynchburg, Elk Ridge, Eureka Coal & Coke Cos., Powhatan, W. Va.

Herbert E. Witherbee, Cleveland, Ohio.

Proposed by C. B. Murray, L. E. Dunham, G. A. Reinhardt.

Born, 1878, Oberlin, Ohio. Shaw Academy, Case School of Applied Science. 1904-06, Oglebay, Norton & Co., Cleveland, Ohio.

Present position: 1908 to date, Mining Engr., Crowell & Murray, Cleveland, Ohio.

Alexander Hamilton Wood, Petros, Tenn.

Proposed by Edward H. Cox, L. C. Crewe, L. C. Glenn.

Born, 1870, Richmond, Va. 1887-89, University of Alabama, studying engineering. 1890-91, Univ. of Virginia, engineering. 1891-92, Asst. Mining Engineer, Tracy City, T. C. I. & R. R. Co. 1892-94, Engineer, T. C. I. & R. R. Co., Whitwell, Tenn. 1895-96, Engineer and superintendent of Bon Air Coal Co., Bon Air, Tenn. 1896-97, State Mine Inspector, State of Tenn. 1897-99, Manager of State Mines, Petros, Tenn. 1899-1905, Manager of Crooked Fork Coal Co., and Big Brushy Coal Co., Petros, Tenn. 1905-11, President, Big Brushy Coal & Coke Co., Petros, Tenn.

Present position: 1911 to date, President of Petros Coal Co., Petros, Tenn.

Steve Howard Worrell, Austin, Tex.

Proposed by W. B. Phillips, A. F. Lucas, G. O. Smith.

Born, 1875, Houston, Texas. 1896-97, Western Reserve Univ. 1899-1901, Univ. of Texas; B. S. 1904-05, Special student of Colo. School of Mines. 1911-12, Special student in Univ. of Tex. 1901-04, Analyst, Univ. of Texas, Mineral Survey. 1904-05, Instructor in Chem., Colo. School of Mines. 1905, Assayer, Supt. and Gen. Supt. of Ladd Metals Co., Portland, Ore. 1906-07, Mgr., Two Kings Mining Co., Chihuahua. 1908, Supt., Margarita Mine, Ocampo, Chihuahua. 1909, Supt., Rey del Oro Mining Co., Mulatos, Sonora, Mexico. 1910, Supt., Guadalupe Mining & Milling Co., Parral, Chihuahua.

Present position: 1910 to date, Chemist, Bureau of Economic Geology, Univ. of Texas, Austin, Texas.

Percy E. Wright, Seattle, Wash.

Proposed by M. C. Butler, G. W. Evans, T. H. O'Brien.

Born, 1878, London, Ont., Canada. High School, and International Correspondence Schools. Twelve years' experience in present line of engineering work. 1902-13, Jeffrey Mfg. Co., of Columbus, Ohio. Design, construction and installation of coal washeries. Last three years District Engr. in charge of Seattle office.

Present position: Consulting Engr., Gale Creek Coal Mines Co., and Wilkeson Coal & Coke Co., Wilkeson, Wash., and Carbon Hill Coal Co., Carbonado, Wash.

Michael Gratian Yatsevitch, Cambridge, Mass.

Proposed by C. H. White, E. D. Peters, Albert Sauveur.

Born, 1880, Bielouosk Mine, Siberia, Russia. 1890-98, Real school (Realschule), Tomsk, Siberia, Russia. 1898-1903, Polytechnical Inst., Kiev, Russia, E. T. 1903-13, Asst. then instructor in chemistry in Kiev Polytechnical Inst. 1906-10, Instructor in technical drawing. 1908-13, Lecturer in Chemistry, Kiev Agricultural College. 1902, summer, The Polytechnical Inst., Tyrianovsk silver mines and works, Siberia. 1903, Summer, Briansk Iron Works. 1912, Summer, Kughsofina Works.

Present position: Visitor to the U. S. by appointment of Russian Ministry of Trade and Industry.

Ralph William Young, Hidalgo, Mexico.

Proposed by C. S. Newcomb, E. Ordoñez, V. M. Braschi.

Born, 1887, West Upton, Mass. Public Schools, Upton, Mass. 1903-06, Worcester Polytechnic Inst., Worcester, Mass. 1906-07, Sheffield Scientific School of Yale Univ.; Ph. B. 1907-08, Grad. Asst. in Mining, Hammond Met. Laboratory, Sheffield Scientific School. 1909, Mucker and time-keeper, Mammoth Mine, Mammoth Copper Mining Co., Kennett, Cal. 1909-10, Asst. to Supt., Quartz Hill Mine, Mammoth Copper Mining Co., Buckeye, Shasta Co., Cal.

Present position: 1910 to date, Cia de Real del Monte y Pachuca, Pachuca, Hidalgo, Mexico, Contractor, Shift Boss, Mine Surveyor, Asst. to Engr. in Charge on examination work, 2d Mine Captain, now Chief Engr.

Associates

de Courcy B. Browne, New York, N. Y.

Proposed by A. E. Borie, E. M. McIlvain, H. A. J. Wilkens.

Born, 1883, Baltimore, Md. 1903, Mining engineering, Lehigh Univ. 1904-09, Bethlehem Steel Co. 1909-10, American Vanadium Co., Eastern Representative.

Present position: 1911 to date, Metallurgical Engr., Goldschmidt Thermit Co., New York City.

James Imbrie, New York, N. Y.

Proposed by H. M. Howe, William Campbell, Robert Peele,

Born, 1881, Bayonne, N. J. Preparatory, Pingey School, Elizabeth, N. J. 1901, Princeton; B. A.

Present position: Junior Partner, Wm. Morris Imbrie & Co.

Frank George Saunders, Tuxpam, Vera Cruz, Mexico.

Proposed by Arthur Payne, C. F. Rand (one additional signature required).

Born, 1868, Indianapolis, Ind. Grad. Indianapolis Public High School.

Present position: Asst. Gen. Mgr., Oil Fields of Mexico Co.

Richard Parran Tinsley, New York, N. Y.

Proposed by F. L. Grammer, J. S. Kennedy, F. Firmstone.

Born, 1867, York Co., Va. 1882, Baltimore City College. 1900-02, New York Univ. School of Commerce, Accounts and Finance; B. C. S. 1910, Univ. of the State of N. Y., Certified Public Accountant. 1882-90, Baltimore & Ohio R. R. Co., Auditing Dept. 1890-92, Wm. C. Seddon & Co., Brokers, Baltimore.

Present position: 1892 to date, Standard Oil Co., now Treasurer.

Thomas J. Walsh, Helena, Mont.

Proposed by H. V. Winchell, W. Scallon, G. T. Wickes.

Born, 1859, Tow Rivers, Wis. 1884, B. L., Univ. of Wis.

Ralston Thornton Wilbur, Spokane, Wash.

Proposed by R. G. Holmes, L. K. Armstrong, J. C. Haas.

Born, 1878, San Francisco, Cal. 1900, Sheffield Scientific School of Yale Univ. 1898, Stanford Univ. 1904, Professor Engineering, Christian Brothers College, St. Louis, Mo. 1911, Supt., Thompson Starrett Co., building construction, Northwest division. 1906, Gen. Mgr., Dolly W. Mine, Portland, Ore., Mexico Portland Cement Co. Member of American Soc. of Mechanical Engineers.

Present position: Head Sales Engr., Hallidie Mch'y. Co., Spokane, Wash.

Leonard Wilson, Salt Lake City, Utah.

Proposed by F. H. Bostwick, C. F. Moore, W. A. Wilson.

Born, 1874, Yorks., England. 1891-94, Leeds Univ., England, general engineering. 1894-1901, Brush Elec. Co., England. Construction, installation, and design of machinery. 1901-05, Stanley Co., Pittsfield, Mass. 1905-09, Power & Mining Dept. G. E. Co., Schenectady, Denver, and Salt Lake. 1909-13, Consulting Engr. practicing in Utah.

Present position: Consulting Engr., Wilson & Ott.

Junior Members

Ralf S. Cockran, Cambridge, Mass.

Proposed by C. H. White, W. S. Weeks, H. L. Smyth.

Born, 1892, Apollo, Pa. 1905-09, Rayen High School, Youngstown, O. 1909-13, Harvard College; A. B. 1913-15, Grad. School of Applied Science, Harvard Univ.

Present position: Student.

Lloyd L. Farnham, Rapid City, S. D.

Proposed by C. C. O'Harra, W. J. Crook, A. S. Halley.

Born, 1891, Sioux City, Iowa. 1897-1906, Grade Schools, Sioux City, Iowa. 1906-10, Sioux City High School. 1909-10, Summers, Asst., Smith & Finley, Civil Engrs. 1911-12, Summers, Asst., Chas. M. Finley, Civil Engr. 1913, Summer, Asst., Office of City Engr., Sioux City, Iowa.

Present position: 1910 to date, Student, So. Dakota School of Mines.

Harold Bertels Fell, Wilkes-Barre, Pa.

Proposed by C. F. Huber, J. M. Humphrey, CharlesENZIAN.

Born, 1889, Wilkes-Barre, Pa. 1895-1902, Public Schools of Wilkes-Barre, Pa. 1902-06, Harry Hillman Academy, Wilkes-Barre, Pa. 1906-07, Mercersburg Academy, Mercersburg, Pa. 1907-12, Princeton Univ., Princeton, N. J.; C. E. 1909-13, Lehigh Valley Coal Co., Wilkes-Barre, Pa., Coal Breaker Construction, Mechanical Dept., Inspection Dept., Inspector of Equipment, Inspector in Inspection Dept.

Present position: 1913 to date, Wyoming Division, Engr. Dept., Lehigh Valley Coal Co., Wilkes-Barre, Pa.

Joseph Cooper Finagin, Rolla, Mo.

Proposed by G. H. Cox, C. R. Forbes, H. A. Beuhler.

Born, 1884, St. Louis, Mo. 1900, Graduate Dozier Grammar School, St. Louis, Mo. 1900-02, Central High School, St. Louis, Mo. 1904-06, Missouri School of Mines, Rolla, Mo. 1912-14, Member of present senior class of M. S. M. 1902-04, Teziutlan Copper Co., Teziutlan, Puebla, Mexico. 1906-07, Teziutlan Copper Co., Teziutlan, Puebla, Mexico. 1907, Oaxaca Smelting & Refining Co., Oaxaca, Oax., Mexico. 1907-09, Esperanza Mining Co., El Oro, Mex., Mexico. 1908, Supt. Rock Quarry, Coyocou, D. F., Mexico. 1909, American Smelting & Refining Co. 1910-12, Carrizo Copper Co., Jalisco, Mexico, Supt. of Smelter.

Present position: Student, Missouri School of Mines.

Percival Sneed Moses, Golden, Colo.

Proposed by F. W. Traphagen, W. R. Chedsey, H. J. Wolf.

Born, 1891, Augusta, Ga. 1900-05, Savannah Preparatory School, Savannah, Ga. 1905-09, Lawrenceville School, Lawrenceville, N. J. 1908-09, Post-Grad. work. 1909-12, Sheffield Scientific School of Yale Univ., New Haven, Conn., Ph. B.

Present position: 1912 to date, Colo. School of Mines, Golden, Colo.

Glenn Howe Van Dorp, Topeka, Kan.

Proposed by W. R. Chedsey, F. W. Traphagen, H. J. Wolf.

Born, 1892, Topeka, Kan.

Present position: Student, Colo. School of Mines.

Change of Status—Junior Member to Member

Alexander I. Abrahams, Frood, Ont., Canada.

Born, 1890, London, England. 1904-08, T. H. H. High School. 1908-11, Columbia College; A. B. 1911-13, Columbia School of Mines; E. M. 1913, Special Sampler with Steptoe Valley Mining & Smelting Co.

Present position: Engineering, Canadian Copper Co.

CHANGES OF ADDRESS OF MEMBERS

The following changes of address of members have been received at the Secretary's office during the month of February, 1914. This list, together with the lists published in *Bulletin* Nos. 76 to 86, and the foregoing list of new members, therefore, supplements the annual list of members corrected to Mar. 1, 1913, and brings it up to the date of Mar. 1, 1914.

ABRAHAM, A. I.	Frood, via Sudbury, Ont., Canada.
ADAMS, HENRY	134 Lawn Ave., Stamford, Conn.
ARGALL, JOSEPH	Nantynwyn Mine, Landover, S. Wales.
BAKER, HUGH C.	Union Bank Bldg., Ottawa, Ont., Canada.
BAGGALEY, RALPH	1291 Shady Ave., E. E., Pittsburg, Pa.
BARNHART, G. H., Min. Engr.	Prest. and Gen. Mgr. Mountain Top Mining Co., P. O. Box 1012, Ouray, Colo.
BLOW, A. A., Min. Engr.	Holston National Bank Bldg., Knoxville, Tenn.
BRADLEY, R. J. H., Min. Engr.	115 Broadway, New York, N. Y.
BRALY, NORMAN B.	822 W. Silver St., Butte, Mont.
BRINSMADE, ROBERT B.	1a Pensador Mexicano No. 3, Puebla, Pue., Mexico
BROWN, W. N.	212 Star Bldg., Washington, D. C.
CALLBREATH, J. F., JR.	526 Munsey Bldg., Washington, D. C.
CASTO, WILLIAM H., JR.	406 Elm St., Anaconda, Mont.

- CLAPP, LAWRENCE R. Silver Lakes Mines, Silverton, Colo.
 CLEVELAND, NEWTON. 623 Insurance Exchange Bldg., San Francisco, Cal.
 COLLINS, G. A. Care Chelsea Hotel, Seattle, Wash.
 COLVOCORESSES, G. M. Cons. Ariz. Smelting Co., Humboldt, Ariz.
 CONNER, ELI TAYLOR, Min. Engr. Room 1315 Stephen Girard Bldg.,
 12th St. below Market, Phila., Pa.
 COOPER, HUGH L., Con. Engr. 101 Park Ave., New York, N. Y.
 COXE, EDWARD H., Mgr. of Operations, La Follette Coal, Iron & Railway Co.,
 La Follette, Tenn.
 CURRIE, WALTER. Care Standard Bank of S. A. W., 10 Clements Lane, London, E. C.,
 England.
 EATON, LUCIEN, Supt. Cleveland-Cliffs Iron Co., Ishpeming District,
 Ishpeming, Mich.
 EDWARDS, WILLIAM S. 2840, 11th Ave., Oakland, Cal.
 ELLIOTT, ROY H. 437 Holbrook Bldg., San Francisco, Cal.
 ENOS, H. C., Min. Engr. 841 Washington Ave., Denver, Colo.
 EVANS, G. S. Care Eastern Smelting Co., Penang, F. M. States.
 FOSS, THEODORE. Mng. Dir., Lyssvensky Mining District of Count P. P.
 Schouvaloff's Successor's Co., Ltd., St. Petersburg, Fontanka 21, Russia.
 FOX, ALFRED, JR. Care Messrs. Graham Rowe & Co., Mersey Chambers,
 Liverpool, England.
 FRICK, FREDERICK F. 306 Hickory St., Anaconda, Mont.
 GAHL, RUDOLF. Inspiration Cons. Copper Co., Miami, Ariz.
 GIDEL, M. H. 1102 W. Galena St., Butte, Mont.
 GOODRICH, HAROLD B. U. S. Bureau of Mines, Washington, D. C.
 GRAVES, McDOWELL. 949 Atlantic Ave., Long Beach, Cal.
 GREENSFELDER, NELSON S. 4528 N. Cheyenne St., Tacoma, Wash.
 GRILL, CHARLES H. Seneca, Cal.
 HAMFELDT, GEORGE K. Oxelosund, Sweden
 HAMMON, WENDELL P. Room 901, 433 California St., San Francisco, Cal.
 HART, C. R. Hermosillo, Son., Mexico.
 HERON, CHARLES M. El Tigre Mine, Yzabel, Son., Mexico.
 HIBBERT, ERNEST. Care British American Nickel Corporation, Nickelton,
 via Sudbury, Ont., Canada.
 HINDSHAW, HENRY H. 317 N. Albany St., Ithaca, N. Y.
 HYSLOP, JAMES E. 1739 Sycamore Ave., Hollywood, Los Angeles, Cal.
 JARVIS, ROYAL P. 1700 Cornell Ave., Knoxville, Tenn.
 JOHNSON, C. B. Room 509, Y. M. C. A., 23d St., New York, N. Y.
 JONES, FAYETTE A. Socorro, N. M.
 JONES, H. EWER. Parliament Mansion, Victoria St., London, C. W., England.
 KEENEY, ROBERT M. Met. and Min. Engr., U. S. Bureau of Mines,
 Univ. of Utah, Salt Lake City, Utah.
 KENT, J. F. Box 763, Huntington, W. Va.
 KIMBALL, GEORGE K., JR. Old Town Min., M. & Trans. Co., Idaho Springs, Colo.
 KINGSBURY, H. C. Care J. J. Kingsbury, 5 Telegraph Chambers, Brisbane,
 Queensland, Aust.
 KOCH, WALTER E. Care Chises Mining Co., Terlingua, Texas.
 KOHLBERG, H. S. Elks Club, New York, N. Y.
 LAWRENCE, SCHUYLER. 16 York Ave., Towanda, Pa.
 LAWRENCE, WILLIS, Gen. Mgr. Chosen Mining Co., Seoul, Korea.
 LAWRIE, H. N. 526 Yeon Bldg., Portland, Ore.
 LOGAN, SPENCER R. 705 East Sixth St., Cherryvale, Kan.
 LUNN, ROBERT, JR. No. 3 Mine, via Sudbury, Ont., Canada.
 MANAHAN, ROBERT F. 711 Mills Bldg., El Paso, Texas.
 MARTIN, ROBERT L., JR. Care Mingo Washed Coal Co., Eugene,
 Mingo Co., W. Va.
 MEYERS, WILLIAM R. Cleveland-Cliffs Iron Co., Gwin, Mich.
 MISHLER, R. T., Asst. Gen. Mgr. Tigre Min. Co., S. A., Esqueda, Son. Mexico,
 via Douglas, Ariz.
 MITCHELL, WILLIAM S. 32 Terrace Road, Medford, Mass.
 MORLEY, FREDERICK H. 2616 Channing Way, Berkeley, Cal.
 MOSIER, MCHENRY. Pilares de Nacozari, Son., Mexico, via Douglas, Ariz.
 MUNROE, H. S., Min. Engr. Concrete, Colo.
 NARAVANE, S. G., Min Engr. 296 Shanwar, Poona City, India.
 NEWELL, G. S. Newell Place, Ave. A., San Antonio, Texas.
 PAINTER, ROBERT K. 40 W. 48th St., New York, N. Y.

PLUMB, CARLTON H.	212 S. Mont. St., Butte, Mont.
POSTLETHWAITE, R. H.	Resident Engr., Imperial Development Co., Calexico, Cal.
POTTER, C. F.	714 Title Insurance Bldg., Los Angeles, Cal.
PROMMEL, H. W. C.	Care Howard Hotel, 1307 Broadway, Denver, Colo.
REECE, FRED B.	Hotel Neurel, Box 221, Globe, Ariz.
RHODES, CHARLES.	Shortland St., Auckland, New Zealand.
ROBESON, A. M.	St. Aubin, Channel Islands.
RODGERS, C. EARL.	Chief Refiner. Dome Mines Co., So. Porcupine, Ont., Canada.
RODGERS, M. K.	Brentwood Park, Santa Monica, Cal.
RYDER, IRVING L.	360 S. 14th St., San José, Cal.
SCHLERETH, C. Q.	Care H. S. Renshaw, 207 Metropolitan Bank Bldg., New Orleans, La.
SCOTT, W. H. HENDERSON.	Care American Consul, Tegucigalpa, Honduras, Cen. Am.
SEARS, MORTIMER A.	3823 Newton St., Denver, Colo.
SHARPLESS, F. F.	Westbury, L. I., N. Y.
SHAW, S. F.	Frisco, Utah.
SHERA, E. L.	Melchers, Successors, Mazatlan, Sin., Mexico.
SOHNLEIN, M. C. F.	Ingenio de Machacamarcas, Cia. Minera de Oruro, Bolivia, So. Am.
STAYER, W. H., Min. Engr.	1626 Wood Ave., Colo. Springs, Colo.
STEWART, JOHN B., Min. Met. Engr.	603 N. Duke St., Lancaster, Pa.
SUVERKROP, E. A.	Care Chile Exploration Co., Chuquicamata, via Antofagasta, Chile.
TAYLOR, HERBERT.	Maplewood, St., Louis Co., Miss.
THOMAS, CHARLES S., JR.	Care Mercantile Trust Co., St. Louis, Mo.
TRAUTERMAN, CARL J., Min. Engr.	Care Bully Boy Co., Marysville, Utah.
TRENGOVE, SAMUEL R.	129 N. Pleasant St., Prescott, Ariz.
TRYON, H. T.	734 E. Sixth St., Tucson, Ariz.
WAGNER, H. R.	123 So. North Carolina Ave., Atlantic City, N. J.
WALLACE, ROBERT.	61 Winthrop St., West Newton, Mass.
WAY, KARL M.	522-523 Lyceum Bldg., Duluth, Minn.
WEBSTER, EDGAR E.	1515 West Monroe St., Sta. C., Chicago, Ill.
WIERUM, HOWARD F.	Care Balaklala Cons. Copper Co., Coram, Shasta Co., Cal.
WILLIAMS, H. L.	307 West 77th St., New York, N. Y.
WOLFLIN, HUGH M.	409 Underwood Bldg., San Francisco, Cal.
WOODS, F. M.	63-64 Independence Bldg., Colo. Springs, Colo.
WOODWARD, W. M. H., Min., Met. Engr.	Idaho Springs, Colo.
WORTH, JOHN C., Min. Engr.	El Rito, N. M.
YATES, A.	14 Winchester Ave., Sedgley Park, Prestwich, Manchester, England.

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DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at a meeting of the Institute. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y. Unless special arrangement is made, the discussion of this paper will close Apr. 1, 1914.

Chlorides in Oil-Field Waters

BY C. W. WASHBURN, WASHINGTON, D. C.

(New York Meeting, February, 1914)

THE waters of many oil fields have been regarded as buried sea water which has been retained in the sediments since the time of their deposition. The preservation of connate water through geological time has seemed improbable to only a few geologists, but there is room for doubt that buried sea water could remain in the strata during their periods of deformation and during the many subsequent epochs of the circulation of meteoric ground-water. Some have even suggested that the calcium chloride water in the deep mines of the Lake Superior region is ancient sea water buried in the Algonkian lavas, but it is hard to understand how such water could be derived from the highly sodic and sulphatic water of the sea. It would seem more plausible to connect the calcium chloride with the highly calcic magmas of the greenstones in which it is found.

Chemical analyses of waters associated with oil differ widely from the composition of sea water, requiring extensive alteration of the latter, if the former is truly its derivative. The first notable difference is the general absence of sulphates from oil-field waters, but this has been explained satisfactorily through reduction by hydrocarbons and organic matter. Oil reduces sulphates with the production of hydrogen sulphide (or sulphur), water, and carbonates (or carbon dioxide).

The second striking difference is in the high ratio of chlorine to sodium. An examination of the analyses of chloride waters from oil fields shows that they contain a large relative excess of chlorine over that in sea water. Moreover, there is difficulty in finding chemical reactions that are probable in nature, by which sea water could be converted into anything like the chloride waters of oil fields. In the latter a large part of the chlorine occurs as calcium and magnesium chloride. This condition might be produced by the removal of sodium carbonate, which, however, cannot be precipitated in the presence of much calcium or magnesium.

Composition of Chloride Waters from Oil Fields

	Sea Water	Pennsylvania		Kansas	
	A	B	C	D	E
Cl.....	55.29 ^a	62.31 ^a	161.80 ^b	49,285 ^c	30,066.0 ^c
Br.....	0.19	0.53	0.70	79	.....
I.....	.....	0.01	.....	8.4	.....
SO ₄	7.69	0.03	0.05	40	.....
CO ₂	0.21	0.27	0.00	0	.....
B ₂ O ₃.....	.....	.....	.....	150	.....
Na.....	30.59	18.35	64.55	} 2,791	} 4,216
K.....	1.11	1.55	5.16		
Li.....	.....	0.04	.....		
NH ₄.....	.....	0.23	.....	.....	.....
Ca.....	1.20	13.86	25.19	1,425	2,792
Ba.....	.....	.....	trace	.....	.....
Sr.....	.....	.....	3.55	.....	.....
Mg.....	3.72	2.53	2.48	2,844	6,310
Al ₂ O ₃.....	.....	0.02	0.00	.....	.....
Fe ₂ O ₃}.....	.....	.....	.....	} 56	} 48
Fe.....	.....	0.25	0.16		
SiO ₂.....	.....	0.02	0.00		
	100.00	100.00	263.64	56,721	43,517
Ratio $\frac{\text{Cl}}{\text{Na}}$	1.8	3.5	2.5	18.2 ±	7.5 ±

a. Percentage of total salts.

b. Grams per kilogram of water.

c. Parts per million (?)

A. Dittmar's summary of the principal salts in sea water, from Clarke, *Data of Geochemistry, Bulletin No. 491, U. S. Geological Survey*, p. 113, 1911. Placed here for comparison.

B. Brine from well 2,667 ft. deep at Conneautville, Pa. Salinity about nine times that of sea water. Analysis by Robinson and Mabery, quoted by Clarke, *loc. cit.*, p. 174.

C. Brine from depth of 6,300 ft. in well near Imperial, Allegheny county, Pa. Analysis by George Steiger, *Journal of the Washington Academy of Sciences*, vol. iii, p. 423, 1913. Well record described by White, *Bulletin of the Geological Society of America*, vol. xxiv, No. 2, pp. 275-282, June, 1913. The salinity is eight times that of sea water.

D. Hudson well, Fredonia, Wilson county, Kan. Depth 400 ft. Analysis by Bailey and Davies, quoted in *Water Supply Paper No. 273, U. S. Geological Survey*, p. 199 (1911).

E. Flowing salt well in Pennsylvanian strata at Lawrence, Kan., depth 1,400 ft. Analysis by Bartow and Thompson, *Kansas Geological Survey*, vol. vii, p. 151 (1902).

The following American analyses were gathered by Hofer,¹ the first four (A-D) being from oil wells near Tarentum, Pa., (analyses by Charles Lenny), and the last two (E-F) from oil and gas wells in Ohio, (analyses by W. J. Root). The high percentage of calcium and magnesium chlorides is noteworthy.

	A	B	C	D	E	F
NaCl.....	3.2000	5.0203	4.7152	32.978	71.645	30.128
NaI.....					0.013	0.024
KCl.....				0.041		
NH ₄ Cl.....				0.007		
CaCl ₂	0.5587	1.6462	0.9657	8.578	18.665	48.969
CaI ₂				0.080		
CaCO ₃				2.764		
MgBr ₂				0.1154	0.271	0.592
MgCl ₂	0.2933	0.3193	0.3132	2.166	9.826	20.201
MgCO ₃				1.377		
BaCl ₂	0.0380	0.0642	0.0759	0.006		
BaCO ₃				0.004		
SrCO ₃				0.059		
Al ₂ O ₃					0.096	0.054
Fe ₂ O ₃						
FeCO ₃				0.038		
SiO ₂				0.102	0.024	0.032
CO ₂				1.953		
CO ₂				0.008		

Two working hypotheses may be entertained to account for the great excess of chlorine over sodium in the water of oil fields. By the first hypothesis, we may explain the disappearance of sodium by the precipitation of sodium chloride from ancient sea water after its burial in the sediments, assuming that the Paleozoic ocean contained less sodium than the modern seas. It is improbable that the average water originally buried in the sediments of oil fields could have been a concentrated brine from which much sodium chloride had been previously precipitated. But the dryness of deep sands in oil fields, and the downward increase in salinity, suggest that beneath the zone of ground-water there is a deeper dry zone from which water has been extracted, possibly through the drying influence of the ascending rock gases, which consist mainly of nitrogen, carbon dioxide, and methane. This process would precipitate sodium chloride on the surfaces of deep rock pores, leaving a residual water relatively rich in the soluble magnesium and calcium chlorides,

¹ *Das Erdöl*, vol. ii, Pl. I, p. 29 (1909). Gives 25 analyses.

which would be driven slowly upward by the rising gas. As the water passed through bodies of shale the adsorption of sodium chloride on clay particles, mentioned by Johnston,² might further increase the relative amount of magnesium and calcium chloride, but since potassium salts are adsorbed on clay more than sodium salts³ the relatively high ratio of potassium to sodium in oil-field waters indicates that adsorption has played a minor rôle in their alteration.

The second and stronger working hypothesis is that the excess chlorine has been added directly as magnesium and calcium chlorides in solutions rising from below. These substances are characteristically high in oil-field waters. Furthermore, it appears that the waters of the Ohio oil fields are converting limestone into dolomite, indicating that the water which accompanied the oil in its invasion of the Trenton limestone was rich in magnesium, as it still remains. Bownocker states that the percentage of magnesium in the limestone increases as one approaches an oil pool, reaching a maximum in the pool itself. Some have suggested that this is merely a question of the relative porosity of dolomite and limestone, but the factor of porosity, although very important, does not explain the whole question. It fails especially to correlate the phenomena with the characteristically high percentage of magnesium in the waters of oil fields, and with the occurrences of secondary dolomite in the coastal fields of Louisiana, Texas, and Mexico. The lenses of dolomite or of dolomitic limestone which cap many of the salt cores of the Gulf coast are clearly secondary deposits which grew within the strata. They were precipitated from the same solutions that deposited the sodium chloride, or at least from solutions which followed the channel made by the plug or core of rock salt. The localized occurrence of dolomite, which is so intimately associated with oil near the coast of the Gulf of Mexico, and in Ohio, Indiana, and Canada, is therefore regarded as the direct or indirect product of solutions rich in magnesium chloride. The bitter brine found in the latter fields is thought to have produced the local dolomitization of the Trenton limestone.

The source of the magnesium and calcium chloride as well as of much sodium chloride may be found theoretically in the emanations from deep-seated basic rocks rich in magnesium, such as the olivine-basalt which is so intimately tied with the occurrence of oil in Mexico, and the peridotite in the dikes of western Kentucky, or the serpentine at Syracuse, N. Y., which are the only igneous rocks known near the northern oil region. Moreover, it is rock of this general character which contains diamonds in South Africa, Arkansas, and other places.

² Discussion of paper by J. A. L. Clerc and J. F. Brezeale, *Journal of the Washington Academy of Sciences*, vol. iii, p. 198 (1913).

³ Clarke: Data of Geochemistry, *Bulletin No. 491, U. S. Geological Survey*, p. 200 (1911).

Stelzner, Bonney and others have proved that the diamonds of the Kimberley district crystallized as an integral part of the magma and that the carbon is of deep-seated origin. In Cuba there is a remarkable series of occurrences of light oil in serpentine. In similar rock Diller has found metallic iron which probably contains carbides. Magnesium-rich magmas therefore are the most probable source of oil (if it be volcanic) and of the accompanying chloride solutions.

The acceptance of the idea that modified volcanic emanations have entered the strata of oil fields simplifies many problems besides that of the relative excess of chlorine. For instance, it furnishes an adequate cause for the localization of the great salt-cores of the Texas, Louisiana, and Chiapas. Harris⁴ finds that the salt domes of Texas and Louisiana have a linear arrangement suggestive of long intersecting fissures. He finds that the amount of uplift of the strata is entirely inadequate to account for the amount of space occupied by the salt plugs, some of which have been penetrated by the drill nearly 3,000 ft., without reaching bottom. He concludes, therefore, that the salt cores are not laccolithic or plug-like intrusions into the sediments, squeezed up from a great hypothetical salt bed in some lower formation, but rather that they have grown by crystallization at the places where they now occur and have not undergone much deformation. In other words, they are great cylindrical concretions of salt 1,000 ft. or more across and over 3,000 ft. high. He believes that the salt and the associated hydrocarbons were gathered by meteoric waters which percolated through the sedimentary strata and rose along the intersections of fissures, where the salt was precipitated because of the decrease in temperature and pressure. The decrease in pressure would cause but a negligible precipitation, practically nothing. Temperature is somewhat more effective, but Lindgren⁵ says: "As the solubility of salt increases only slightly with increase of temperature (35.69 per cent. at 10° C.; 39.12 per cent. at 100°; 44.90 per cent. at 180°), only the increment could have been precipitated as the temperature of the ascending current was lowered, and hence the quantity of primary salt required by this hypothesis is incredibly large." Let us assume that the solutions cooled as fast as the normal underground heat gradient, or about 21° C. in ascending 2,000 ft. This would precipitate about 2 per cent. of the total salt in a

⁴ *Bulletin No. 429, U. S. Geological Survey* (1910). The alignment of the salt domes was first observed by Captain A. F. Lucas: *Rock-Salt in Louisiana, Trans.*, xxix, 463, Fig. 1 (1899). Captain Lucas was also the first to observe the geological relations of the salt cores with reference to the occurrence of oil, which he proved by drilling the famous "Lucas gusher" at Spindletop. Cf. Robert T. Hill: *Journal of the Franklin Institute*, vol. cliv, pp. 143, 225, 263 (Aug.-Oct., 1902). A. F. Lucas: *Science*, vol. xxv, pp. 961-4 (June 21, 1912). *Economic Geology*, vol. vi, No. 4, p. 380 (June, 1911).

⁵ *Mineral Deposits*, p. 288 (1913).

solution saturated at 100°. In other words, the salt cores would represent only about 2 per cent. of the total amount of sodium chloride which had risen in the fissures, the rest having been carried beyond the top of the cores and lost. The salt cores in this country and Mexico number several hundred and their total volume is many cubic miles. The theory of Harris, if not modified, requires a supply of roughly 50 times as many cubic miles of salt.

Yet the "concretionary" theory of Harris has much in its favor, since it meets the mechanical requirements of the problem better than any other. The chemical difficulty can be met if the salt domes have been the *loci* of the escape of solutions carrying a common ion, either of sodium or of chlorine. Analyses of some volcanic waters show an abundance of sodium chloride, and others of sodium sulphate or carbonate, but these do not meet the requirements of the present problem. From the character of the water and from the presence of secondary lenses of dolomite, one may infer that the precipitation was produced by the intermingling of concentrated salt solutions with brines rich in magnesium and calcium chloride. The former were probably derived mainly from the sedimentary strata as suggested by Harris, but the latter probably rose from underlying plugs of olivine basalt which failed to reach the surface.

Plugs and dikes of this type of rock are common in the coastal plain of Mexico, where they have about the same relation to the occurrence of oil as do the salt cores in Texas to the north or in Chiapas to the south of them. The chlorine probably escaped from the magma as free chlorine, as hydrochloric acid, and as chlorides of ammonium, calcium, magnesium, and sodium. If the igneous plugs are not too deeply buried beneath the plains it is probable that large quantities of hydrochloric acid passed up through the overlying fractures made by the intrusion of the plug. This is the most effective precipitant of common salt, and in the case of the fields about the Gulf of Mexico, the evidence of volcanic action is so strong as to suggest that hydrochloric acid may have played an important rôle in the precipitation of the salt above the volcanic plugs. Also magnesium and calcium chlorides would be quite effective to precipitate rock salt, and if the ascending igneous emanations passed through many strata before reaching the horizon of the salt cores it is certain that the hydrochloric acid would be all converted into chlorides, largely into the chlorides of calcium and magnesium. For our present argument it is immaterial whether the chlorine ions were attached mainly to hydrogen, to calcium, or to magnesium. According to Nernst's law, any of these probable chlorides would precipitate sodium chloride from a concentrated solution. In this way masses of salt derived from the sediments would be formed

where the sedimentary solutions mixed with the rising solutions of volcanic chlorides, *i.e.*, directly above the deeply buried plugs.

Thus the volcanic hypothesis offers a simple explanation of the salt and dolomite problem of oil fields, and the relative excess of chlorine in the associated water may be regarded as a possible indication of the entrance of volcanic emanations, which in most cases have been greatly modified by their long ascent through the rocks.

DISCUSSION

A. F. LUCAS, Washington, D. C.—I have long held the opinion that igneous rock may underlie the salt domes of Louisiana, Texas, and elsewhere, resembling laccoliths, batholiths, or sills, and an unsuccessful attempt to prove this was made at my instance by the drilling of the Knapp well at Belle Isle, La., which passed through over 3,000 ft. of rock salt (the first time to my knowledge that a salt dome has been pierced), then entered into sedimentary, striking first an oil sand giving about one barrel of red paraffine oil, then limestone, calcite, or dolomite (not positively ascertained), until a total depth was reached of about 3,300 ft., when the well was lost by the collapse of the casing.

At the extreme bottom the drill was working on very hard formation, which it could not penetrate, although repeated attempts were made, nor was it possible to secure samples of this rock, which, from its extreme hardness, I surmised to be possibly some igneous rock, or perhaps iron pyrite.

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Geology and Technology of the California Oil Fields

BY RALPH ARNOLD AND V. R. GARFIAS, LOS ANGELES, CAL.

(New York Meeting, February, 1914)

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INTRODUCTION

THE following paper has been prepared to meet a demand for a concise review of the California oil industry. It is based largely upon information

secured during the course of the senior author's professional activities, and upon data obtained during the course of investigations for the U. S. Geological Survey and the U. S. Bureau of Mines. Considerable information has been obtained from other sources, and to those who by publication or otherwise have contributed, the writers extend their thanks.

GENERAL STATEMENT

In 1912 the United States produced¹ 63.25 per cent. of the world's production of petroleum, Russia, its nearest competitor, yielding only about 19 per cent. The production in 1912 reached 222,113,218 barrels (or 29,615,096 metric tons), compared with 220,449,391 barrels in 1911. The average price per barrel in 1912 was nearly 74 c., as against nearly 61 c. in 1911. The total value, therefore, increased 22.20 per cent., or \$163,802,334 above the value for the previous year. These figures of production include pipe-line runs, independent railroad shipments, oil piped direct to refineries, and the crude oil consumed as fuel in oil production. The production does not include oil in storage in the field which has not been sold.

California ranks first of all the States in the Union in the production and value of petroleum, the total output in 1912 being 86,450,767 barrels, or an increase of 6.55 per cent. over the production of the State in 1911. Consumption, however, increased 18.8 per cent. Stocks increased from 44,240,118 barrels at the end of 1911 to 47,552,392 barrels at the end of 1912, when consumption had nearly equaled production. The average price received was 45.4 c. per barrel in 1912, against 47.7 c. in 1911.

Oil stands first in value in the State's mineral products, the output in 1913 being valued at \$43,500,000² as against \$20,000,000 for gold, its nearest competitor. Eleven districts furnish the product, and these, in the order of their importance in 1912, are listed in the table on the opposite page.

With the exception of a negligible quantity of oil carrying some paraffine, all of the oil from the California fields has an asphalt base. About 40 per cent. is what is commonly known as heavy or fuel oil, while about 60 per cent. is passed through stills for topping or refining, the residuum being used as fuel. The bulk of the production is, therefore, used for fuel or road dressing, either in its crude state or as residuum. Most of it is utilized in the Pacific States and Canada, but some is exported to the adjacent States to the east, and to Hawaii, Japan, Alaska, Panama, and South America.

¹ Figures taken from *Mineral Resources, U. S. Geological Survey.*

² Preliminary estimate of the State Mineralogist.

Production of Petroleum in California for 1912

In Barrels of 42 gal.

Valley Districts:

Coalinga.....	19,911,820
Lost Hills.....	1,367,359
McKittrick.....	5,881,996
Midway.....	23,928,368
Sunset.....	6,509,093
Kern River.....	12,558,439

70,157,075

Coast Districts:

Santa Maria.....	5,909,300
Summerland.....	65,376
Santa Clara Valley.....	746,780
Los Angeles.....	2,670,463
Puente Hills.....	6,881,650
Other fields.....	20,123

16,293,692

Total.....	86,450,767
------------	------------

The proved area of oil-producing territory in California is approximately 100,000 acres, and this practically represents the possible acreage, as it does not seem probable that any more large districts will be discovered. For that reason, further development doubtless will be carried on within the limits of the proved fields or along the line of minor extensions of the same. Assuming the possible productive area confined to the present districts, California is still destined, according to the most conservative estimates, to hold premier place among the oil-producing States of the Union for many years.

LOCATION OF OIL DISTRICTS

California is the southernmost State of the United States of America adjacent to the Pacific ocean. It includes an area of 158,360 square miles, comprised within an irregular strip about 200 miles wide, roughly paralleling the coast for 800 miles. The trend of the California coast line is governed by that of the western flanks of the Coast Ranges. These mountains have an average elevation of 2,500 ft. and extend from the northern boundary of the State in a southeasterly direction for 550 miles, changing at Point Conception to a more easterly trend, which is followed to the Mexican frontier, 250 miles southeast. This natural western boundary is duplicated along the eastern portion of the State by the Sierra Nevada, a range of lofty peaks rising, on an average,

10,000 ft. above sea level and culminating in Mount Whitney, the highest mountain in the United States, 14,500 ft. high. The Sierra roughly parallel the Coast Ranges throughout the central half of the State, the depression between these mountain masses forming the Sacramento and San Joaquin valleys, with a total length of 400 miles and an average width of 40 miles. The northern part of this depression is drained by the Sacramento river, the southern part by the San Joaquin, which joins the Sacramento and discharges through a narrow channel into San Francisco bay. North of the Sacramento valley and south of the San Joaquin, the Coast Ranges and Sierra Nevada mountain systems coalesce into extensive regions of irregular mountains and valleys.

Valley Districts.—All the commercially productive oil fields in California are located in the southern half of the State along the flanks of the Coast Ranges, as shown on the map, Fig. 1. The most important developed fields are situated along the southwestern rim of the San Joaquin valley and extend, with intervening unproductive areas, for about 100 miles. The San Joaquin valley districts include the Coalinga, Lost Hills, McKittrick, Midway, Sunset and Kern River. The first is in Fresno county, about 250 miles southeast of San Francisco, and the last five in Kern county, from 80 to 110 miles further southeast. The Sunset district extends around the angle at the southwest corner of the valley, and the Kern River district lies on the lowest foothills of the Sierra Nevada, near the southeastern corner of the San Joaquin valley.

The Valley districts produced in 1912 over 70,000,000 barrels of oil, or about 81 per cent. of the total output of the State. With the exception of the oil from Lost Hills, Belridge, and local areas in the other fields, which produce refining grades up to 40° Baumé gravity (0.8235 sp. gr.), the product of the Valley districts is a typical fuel oil, averaging about 16° Baumé (0.9589 sp. gr.).

Coast Districts.—The fields which yielded in 1912 the remaining 20 per cent. of the State's production are situated on the western flanks of the Coast Ranges in secondary ranges and valleys merging into the main system. These fields extend from Santa Barbara county on the north to Orange county on the south, throughout a distance of about 150 miles. The greatest portion of the yield of these fields is of lighter gravity than the product from the Valley fields, the oil being used largely for refining.

The Santa Maria district is located on the low rolling hills near the coast of Santa Barbara county, about 280 miles southeast of San Francisco and 200 miles northwest of Los Angeles. The Summerland district lies immediately on the coast, 120 miles northwest of Los Angeles, while the Santa Clara valley district includes the region from the Newhall field in Los Angeles county, 40 miles northwest of Los Angeles, to the Ojai Valley field in Ventura county, 50 miles further west. The topography of the Santa Clara valley district consists largely of hills and

valleys, some of the oil fields being located in rugged and almost inaccessible places. The Los Angeles district lies on or along the edge of the great coastal plain in or adjacent to the city of Los Angeles. The Puente Hills, or Fullerton district, as it is sometimes called, lies on the south flank of the Puente hills from 12 to 30 miles southeast of Los Angeles.

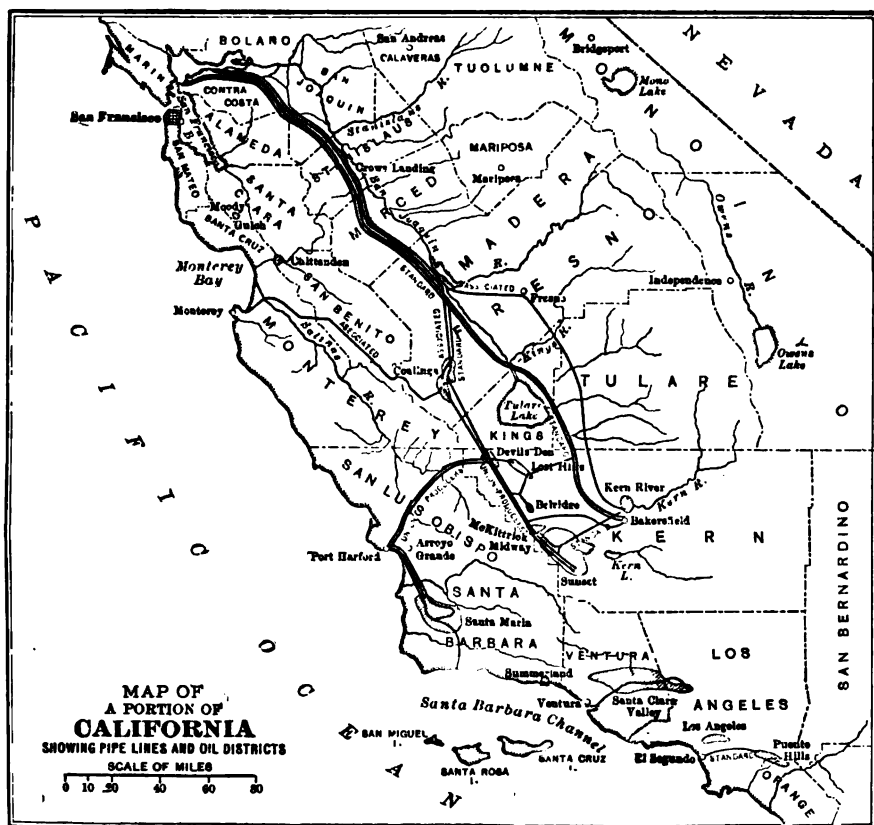


FIG. 1.—MAP OF A PORTION OF CALIFORNIA SHOWING PIPE LINES AND OIL DISTRICTS.

HISTORICAL

The oil industry in California owes its origin to asphaltum mining. The first definite effort to develop oil in California was made in the Ojai valley, Ventura county, in 1867, when a shallow well was drilled near one of the numerous brea or asphaltum deposits of this region which had been worked for some time previous. Owing to the lack of proper tools for operation, and insufficient knowledge concerning the handling of the heavy oil obtained, this well was not a success. Following the drilling

of the Ojai valley well there was a lapse of several years and then came more determined development work in the region of Pico canyon and Newhall, in western Los Angeles county. Here a light oil suitable for refining was obtained, and a little later development work in Adams canyon, south of Santa Paula, Ventura county, and in the Puente hills, southeast of Los Angeles, was rewarded by the finding of refining oils. No use was known for the heavy oils at that time, and, as a consequence, prospecting in regions where these were known to exist was not pushed.

The discovery of the Los Angeles and Summerland districts in 1894 marks the beginning of the fuel-oil production in California. Previous to this year the maximum yearly production of the State had been less than 500,000 barrels. The Coalinga field was the first commercially productive district in the San Joaquin valley, yielding during its first year, in 1896, about 14,000 barrels.

The year of 1900, when the Kern River district was discovered, marks the beginning of the important development and the initiation of California as a factor in the world's oil production.

A table of the yearly production from 1865 to 1912, inclusive, is given herewith (pp. 468 and 469.) Details of the history of the industry will be given in discussing each separate field.

PRESENT POSITION OF THE LARGER COMPANIES

In order to understand the present situation of the oil industry in California, it is well to discuss the early history of the oil-field regions before the fields were discovered, particularly in regard to land ownership.

After California was ceded by Mexico in 1846, it became a national necessity of the greatest importance to connect the two seaboard by rail. As a result, railroad companies were organized to build a trans-continental railroad from Ogden, Utah, to San Francisco, and later from New Orleans, La., through Galveston, Texas, to San Francisco.

Southern Pacific Railroad Co.—As a special inducement, or bonus, to the railroads, the U. S. Congress granted in certain regions every alternate square mile of government land within a zone along the railroad lines varying between 10 and 20 miles in width. It so happened that a large portion of the land in which the San Joaquin valley districts are now located came within the 20-mile zone allotted to the Southern Pacific railroad for building its line along the valley, and as a consequence every alternate section of land within this zone became the property of the railroad. (In this connection it should be remembered that these Valley fields yield at present about 80 per cent. of the State's production.) When some of these lands were granted to the railroad, the government reserved the mineral rights on same, but at the time neither the government nor the railroad officials knew of the existence of the oil deposits. Be-

fore the discovery of the Valley fields, the railroad company sold a small portion of this land and rented a larger amount. However, it still retained and at present owns practically every alternate section of land throughout the greater portion of the San Joaquin valley fields. The Coast fields being located in the fertile lands nearer the ocean were owned in large areas—Spanish grants—by the descendants of the Spanish settlers, and little, if any, of the oil territory on the coast was public domain and as such granted to the railroad.

Kern Trading & Oil Co.—In order to handle the oil business of the Southern Pacific Railroad Co., the Kern Trading & Oil Co. was organized, and the oil lands of the railroad transferred or leased to the new company. The K. T. & O., as it is commonly known in the State, has not carried on systematic development in all of the districts in the San Joaquin valley, but has contented itself with protecting its property lines by drilling opposite neighboring wells. At present this company controls about 10 per cent. of the total yield of the State, all of which is used by the Southern Pacific Railroad Co. for fuel in locomotives and shops.

Associated Oil Co.—In 1902 a number of oil-producing properties in the Kern River district consolidated under the name of the Associated Oil Co. and extended their operations to practically every district in the State. Soon afterward this company, in conjunction with the Southern Pacific, organized the Associated Pipe Line Co. for the purpose of building pipe lines from the Valley fields to San Francisco bay, each company being entitled to one-half the carrying capacity of the line. In 1905 the Associated became a subsidiary of the Southern Pacific when the latter obtained the control of a majority of the Associated stock. The Associated and subsidiary oil companies control about 22 per cent. of the State's production, which, added to the production of the Kern Trading & Oil Co., brings the total oil controlled by the Southern Pacific group to about 32 per cent. of the production of California. The Southern Pacific and the Kern Trading & Oil Co. control the greater portion of the undeveloped land in proved territory¹ which contains the bulk of the future oil supply of the State.

The Southern Pacific, through its subsidiary companies, controls pipe lines from the Valley fields to tidewater, with a combined daily capacity estimated at 58,000 barrels, and pipe lines from some of the Coast fields to the seaboard with an aggregate daily capacity of about 25,000 barrels. The Associated Oil Co. owns a fleet of tank steamers plying mainly along the Pacific Coast States and Canada.

Standard Oil Co.—Early in the oil history of California, the Standard Oil Co. obtained control of the Pacific Coast Oil Co. and became interested

¹ The United States government has instituted suits against the Southern Pacific railroad in an effort to recover a part of these lands.

in the transporting, marketing, and refining of oil. As the industry grew it built pipe lines to every important district in the State, also extensive refineries near San Francisco and Los Angeles. Lately this company has become an important factor in oil production, particularly in the Valley fields, and at present controls over 30 per cent. of the production of the State and the greater part of the refining industry. The Standard pipe line system from the Valley fields to San Francisco bay has an aggregate capacity of about 65,000 barrels per day, the coast system of pipe lines having a daily estimated capacity of 30,000 barrels. This company also owns an up-to-date fleet of tank steamers plying along the Pacific seaboard and to foreign ports.

Union-Agency Companies.—The Union Oil Co. was organized in 1890, and at present owns productive oil lands in nearly every district in the State; a fleet of tank steamers; refineries near San Francisco and at Port Harford; and pipe lines from the different districts to tidewater. It also owns a pipe line across the Isthmus of Panama, used to supply fuel to the different plants in the Canal zone.

About four years ago a number of independent producers in the Valley fields organized the Independent Producers Agency in order to market to better advantage their combined product, which at that time aggregated between 15,000 and 20,000 barrels of oil per day. It soon became apparent to the Agency members that in order to dispose of their oil to any but the California marketing companies owning pipe lines it would be necessary for the Agency to transport its oil to the coast. To this end the Agency enlisted the aid of the Union Oil Co., and as a result the Producers Transportation Co. was organized to build a system of pipe lines connecting the Valley districts to Port Harford. The Union Oil Co. acts as the marketing agent for the oil produced by the companies in the Agency. At present there are about 170 companies in the Agency, their combined production, and that of the Union Oil Co. which is handled in conjunction with the Agency's oil, totaling about 25 per cent. of the State's yield.

General Petroleum Co.—Two years ago the General Petroleum Co. was organized, acquiring a number of the small independent properties. Later, the General Pipe Line Co. was organized as an affiliate of the General Petroleum Co., and built a pipe line connecting the Midway district to Los Angeles. Last year the General Petroleum Co. came into prominence when it secured an option to buy the Union Oil and subsidiary companies. If this purchase is consummated, the General Petroleum, Union Oil, and Independent Producers group will become one of the most important in the State and will control about one-third of the total present yield.

Royal Dutch-Shell Co.—During the present year—1913—the Royal Dutch-Shell group acquired the California Oilfields, Ltd., one of the

largest companies outside of those just mentioned, and one or two other properties in the Valley fields, and although it is estimated that the present combined production of these properties represents a small percentage of the total yield of the State, it is natural to suppose that such a strong organization as the Royal Dutch-Shell Co. will eventually assume a more important position in the California petroleum industry.

It is estimated that there were 290 oil-producing companies in the State during 1912, with a combined production of some 86,450,000 barrels for the year, and that about 87 per cent. of this was controlled by the three groups first mentioned through purchase from independent consumers, royalties from rented oil lands, and production from their own properties, the remaining 13 per cent. being marketed by small independent companies.

MARKET CONDITIONS AND PRICE OF OIL

The Railroads and the Price of Oil.—The largest consumers of oil in the State are the railroads, it being estimated that in 1912 the Southern Pacific alone used 11,680,000 barrels, or 13.5 per cent. of the total production of the State, or about 16.4 per cent. of the production of the Valley fields, from which the fuel supply of the railroads is obtained almost entirely. It is thought that the Kern Trading & Oil Co. furnished the Southern Pacific railroad only a portion of the oil consumed, the remainder being obtained from other sources. The Atchison, Topeka & Santa Fé railroad also owns a large acreage of proved land in the Midway district and lesser holdings in the Kern River and Puente Hills districts, and produces much of its own oil, but still buys some. It is evident, therefore, that it is to the railroads' advantage to try to hold the price of fuel oil as low as possible. Again, there will be no immediate need to develop further the railroad oil lands if the independent producer, who must continue to operate his producing wells under the present unfavorable conditions, as a matter of self preservation, is compelled to sell his product at a price below what it costs the railroad companies to produce it, for under these circumstances the required amount is readily and cheaply obtained by the railroads while they save their own supply for future demands.

At present the Standard Oil Co. produces little heavy oil and does not buy any under 18° Baumé (0.9459 sp. gr.). It is not concerned, therefore, about the price at which the heavier grades are purchased by the railroads. True this company sells in the State and exports residuum from its refineries for fuel, but the profits derived from the sale of this heavy oil are believed to be small compared with those derived from the sale of its lighter refined products. For these and other reasons which have been made clear in the course of time, the Standard Oil Co. and the

Southern Pacific Co. and the latter's subsidiaries have worked in harmony as regards their influence toward keeping the price of crude oil in California as low as possible. This condition was brought about and made possible by the control of the oil-transportation facilities by the two companies, and has been sustained by the overproduction occasioned by the bringing in during the last three or four years of the large flowing wells in the Valley districts.

Position of the Small Producer.—Under these conditions an independent company in the Valley fields, producing the average quality of fuel oil, had to sell at the price offered by the Standard Oil or Southern Pacific Railroad companies, or, as an alternative, ship the product by rail to the coast and sell it in the open market. In most cases this last course did not materially improve conditions, as the railroad freight on oil from the Valley fields to San Francisco added to the cost of transporting the oil from the property to the railroad, and to the cost of production, left, as a rule, little or no margin of profit at the price paid for the oil at tidewater.

Effect of the Advent of an Independent Transportation Company.—In an effort to improve these conditions, the Independent Producers Agency was organized, and later, with the help of the Union Oil Co., the Producers Transportation Co. built pipe lines from the valley to the coast. The Producers Agency became a sort of clearing house for a large portion of the oil produced by independent companies, charging for its handling $\frac{1}{2}$ c. per barrel. The Agency has no interest in the transportation company, the only tie being a contract which binds them for a term of ten years beginning with 1910. The Producers Transportation Co. charges the Agency's members from 17 to 22 c. per barrel for piping the oil from the fields to Port Harford, on the coast. The Union Oil Co. acts as the selling agent for the Agency, and is empowered to make contracts, subject to the Agency's approval, for the whole or any part of the combined production.

From the foregoing it will be noted that up to the present time the local marketing conditions of the San Joaquin valley oil produced by independent operators have only been slightly improved by the organization of the Producers Transportation Co.; in fact, with oil selling at San Francisco for 70 c. per barrel, there is practically no opportunity for the producer to market his oil there at a profit, as Port Harford is about 215 miles from San Francisco and the oil has to be transported in tank steamers. It is expected by many familiar with the oil situation that with the passing of the present period of overproduction the price of oil will be materially increased, as soon as the large companies are compelled to draw from their stock to fulfill their selling contracts. While the producer, up to the present time, has benefited only slightly by the organization of the Agency and the Producers Transportation Co.,

this latter company, on the other hand, has become a very lucrative enterprise. It is evident, therefore, that even under the present unfavorable conditions, the position of the independent producers would be improved had they been able at the outset to build their own pipe line and operate it to their mutual benefit.

Oil Reserve and Future Price of Oil.—The probable productive oil territory of California is to all intents and purposes outlined to-day, and the same statement holds good for all of the Pacific coast of the United States, for outside of California there is within the region mentioned, with the possible exception of Alaska, no commercial oil field, nor do the geologic conditions offer any hope of any important field ever being developed.

The proved area of California consists of approximately 100,000 acres, or 156 square miles, outside of which there is a relatively small amount of probable territory, and this latter area is becoming more and more restricted each year through the adverse results obtained in the drilling of test or "wild-cat" wells at the most favorable localities. This proved acreage contains an available reserve which the senior author has estimated at from four to eight billion barrels of oil, the variability in estimate being due to the uncertain effects which such factors as the ingress of water, etc., have on the quantity which can be recovered at a commercial profit. The oil production of California for the calendar year 1913 was about 97,000,000 barrels, which is the maximum for any one year up to date. At this rate of production, the California fields would last only 40 to 80 years, but it is quite obvious to any one who has studied the normal rate of decrease in the production of individual wells, even in a cursory manner, that it will take a most vigorous campaign of drilling to keep up the present rate, let alone increase it to any appreciable extent. Furthermore, within a short time the production will begin to decrease in spite of the most extensive drilling, as it has done in other States, so that it will require from 50 to 100 years in which to recover the available supply.

Roughly speaking, it has been found by experience that to simply maintain the production of any group of wells in California, it is necessary to drill one new well each year for every five producing during that year. In other words, the normal decrease is nearer 20 per cent. than 10 per cent. as was estimated when the field gas pressure was high.

Although the production in California has grown rapidly during the past few years, the consumption has nearly kept pace. At present the oil in storage in the State is about 50,000,000 barrels, or only about a six months' supply. For the first half of 1913 the surplus production over consumption averaged only 2,085 barrels per day; for October the average was about 18,000 barrels per day and practically all of this came from the flush yield of two or three big gushers which were recently brought

in and the production from which is even now rapidly falling off. In estimating future production, the flush yield of gushers must be taken into account, but in this connection it should be borne in mind that these big wells are becoming less and less common and their period of abnormally large flow shorter and shorter as the fields become developed and the field gas pressure is consequently reduced.

As a concluding statement concerning production, it is the senior author's belief that the total yield of California for any one year will never go much, if any, over 100,000,000 barrels and that the time will come within the next year or two when the maximum production will be reached, after which, the curve of production will be a descending one. Such has been the history of all of the older fields in this country and such is the logical result to be expected in California. With the increasing uses and markets for oil resulting in a constantly increasing consumption, it is obvious that the price of oil will go up rapidly the minute the general public realizes that the reserves are being drawn upon to meet the demand.

The standard for fuel values is coal, and compared with coal on the Pacific coast, heat unit for heat unit, oil is worth 93 c. per barrel at the well. Considering the many acknowledged advantages which oil has over coal as a fuel, and the many uses for which oil is more valuable than as a fuel, it will be clear to the thoughtful man that the price of even fuel oil will eventually go much higher than the standard set by coal. True, certain of the larger companies in the California field are not talking in an optimistic vein regarding the immediate future price of oil, but their almost feverish activity to acquire additional acreage and production speaks louder than words as to their real beliefs in the matter.

TRANSPORTATION

In order to understand the conditions affecting oil transportation from any district to the coast, it is necessary to keep in mind whether the district in question is located along the western (Coast districts) or eastern flanks (Valley districts) of the Coast ranges. Transportation from the Coast districts to tidewater is a comparatively simple and inexpensive operation, the distance that the oil has to be piped never being over 50 miles. Ideal conditions are attained in the Los Angeles field, where producing wells are located about 1 mile from the business center of the city of Los Angeles, which has an estimated population of 400,000. The Puente Hills district lies from 12 to 25 miles east of the city of Los Angeles and about 30 miles from Los Angeles harbor. Another district advantageously located is the Summerland, where the wells are located on wharves and drilled under the Pacific ocean. Nearly all the lines

joining the Coast fields to Los Angeles or tidewater are laid over flat or low rolling ground, and their operation is further facilitated by the high gravity of the oil produced in most of the fields. In fact, nearly all the lines from the Santa Clara valley fields transporting light oils are operated without pumps, the oil gravitating for about 50 miles to Ventura, on the coast. The good quality of the oil and the low cost of transporting it to the market greatly benefit the independent producer in the Coast fields, as the large marketing companies are anxious to obtain all the light oil in these fields and the heavier grades can be readily disposed of at a good price to the small consumers in the cities along the coast. Unfortunately, the most productive fields (yielding 80 per cent. of the State's production) are separated from tidewater by the Coast ranges, and in order to transport the oil to the coast it is necessary to pipe it for 280 miles along the San Joaquin valley and out to San Francisco bay, or from 110 to 160 miles over the Coast ranges to Monterey bay, Port Harford, or Los Angeles. The cost of building and operating these pipe lines can be afforded only by organizations with large financial backing and which control enough production to keep the lines in continuous operation at their full working capacity. It is evident, therefore, that the cost of piping the bulk of the State's yield (which represents practically all the fuel oil produced) from the Valley districts to tidewater has a most vital effect on the oil industry of the State.

Pipe Lines from the Valley Districts to Tidewater

The pipe lines from the Valley districts to the sea coast are owned or controlled, either directly or through some subsidiary company, by the Standard Oil, Southern Pacific, Union Oil, and General Petroleum companies. The Valley system of the Standard consists of:

Standard Oil Co.

Estimated
Daily Capacity
Barrels

Two 8-in. trunk lines 275 miles long from Kern River district to San Francisco bay.....	60,000
One 8-in. branch line 28 miles long from Coalinga to Mendota.....	28,000
Two 8-in. branch lines 36 miles long from Kern River to Midway...	65,000
One 8-in. branch line 21 miles long from Lost Hills to Pond.....	20,000

The working capacity of the Standard Oil Co.'s Valley system connecting all the San Joaquin districts to Point Richmond in San Francisco bay is that of the two trunk lines, or about 60,000 barrels per day.

Southern Pacific Railroad

	Estimated Daily Capacity Barrels
<i>Associated Pipe Line Co.</i>	
One 8-in. trunk line 280 miles long from Kern River to San Francisco bay.....	13,000
One 8-in. trunk line 285 miles long from Sunset district to San Francisco bay.....	30,000
<i>Associated Transportation Co.</i>	
One 6-in. trunk line 110 miles long from Coalinga district to Monterey bay.....	15,000

The total daily capacity of pipe lines controlled by the Southern Pacific Railroad Co. from the Valley districts to San Francisco bay is 43,000 barrels, and from the Coalinga district to Monterey bay 15,000 barrels, making a grand total of 58,000 barrels as the carrying capacity of this company's lines from the Valley districts to tidewater.

Union Oil Co.

	Estimated Daily Capacity Barrels
<i>Producers Transportation Co.</i>	
Two 8-in. trunk lines 70 miles long from Junction to Port Harford..	50,000
With 8-in. branch lines to Coalinga, Kern River, Sunset, Midway, and Lost Hills.	

The Union Oil Co., therefore, controls pipe-line transportation facilities from all the San Joaquin valley districts to Port Harford, having an aggregate daily capacity of about 50,000 barrels. It should be noted that Port Harford is situated 215 miles southeast of San Francisco, and 200 miles to the northwest of Los Angeles.

*General Petroleum Co.**General Pipe Line Co.*

This company has one 8-in. pipe line from the Midway district to Los Angeles harbor, a distance of 158 miles, the estimated daily capacity of which is about 30,000 barrels. A branch 8-in. line 35 miles long runs from Lebeck Station to Mojave, where the oil is topped before shipping by rail to the south and east of Mojave.

Summary

	Barrels
Total daily carrying capacity of Valley system of pipe lines....	198,000
Daily production of Valley districts during 1912.....	194,500
Available daily pipe-line capacity in excess of production, assuming all lines working at their rated capacity.....	3,500

Pipe Lines from the Coast Districts to Tidewater

The Santa Maria and Santa Clara valley oil districts are connected by pipe lines to seaboard, while practically all the oil produced in the Los Angeles and Puente Hills districts is piped or hauled into or near Los Angeles, where it is used as fuel or by refineries.

*Pipe Lines from Santa Maria District to Seaboard.**Standard Oil Co.*

	Barrels
One 8-in. line 32 miles long from Orcutt to Port San Luis, estimated capacity.....	20,000

This line is only intermittently used, as the oil controlled by the Standard in the Santa Maria district is but a very small fraction of the capacity of the line.

*Southern Pacific Railroad Co.**Associated Pipe Line Co.*

Barrels

One 8-in. line 35 miles long from Santa Maria to Gaviota, estimated capacity.....	15,000
One 8-in. line 30 miles long from Orcutt to Port Harford.....	Idle

Half of this amount, or 7,500 barrels, belongs to the Associated Oil Co., the Union Oil Co. controlling the other half.

Union Oil Co.

This company, through its subsidiaries, controls:

Barrels

One 8-in. line 50 miles long from Santa Maria to Port Harford	
One 6-in. line 30 miles long from Santa Maria to Port Harford, estimated capacity.....	40,000
One 2-in. line 30 miles long from Santa Maria to Port Harford for gasoline.	

This company makes use only of from 10,000 to 15,000 barrels per day, this being the oil controlled and produced in Santa Maria.

*Other Companies**Pinal-Dome Oil Co.*

One 4-in line from Santa Maria field to a topping plant at Betteravia for crude.	
One 2-in. line from Santa Maria field to a topping plant at Betteravia for gasoline.	

Summary

	Barrels
Total daily carrying capacity of Santa Maria system of pipe lines, assuming idle lines operating at full rate of capacity.....	90,000
Daily production of Santa Maria district during 1912.....	16,190

It will be seen that this district is provided with ample pipe-line transportation facilities to seaboard, being able to carry over five times the production of the field during 1912.

Pipe Lines from the Santa Clara Valley District to Seaboard

(Operating mostly by gravity)

Standard Oil Co.

	Barrels
One (2-in., 3-in.), 44 miles long from Newhall field through Santa Clara valley fields to Ventura, estimated daily capacity.....	1,400

Union Oil Co.

	Barrels
One 4-in. line 45 miles long from Torrey canyon to Ventura, estimated daily capacity.....	3,000

Summary

	Barrels
Total daily carrying capacity of Santa Clara valley system of pipe lines to Ventura.....	4,400
Daily production of Santa Clara valley fields for 1912 about.....	2,040

These fields are, therefore, supplied with pipe lines having an aggregate capacity of about twice their present production.

*Pipe Lines from the Los Angeles and Puente Hills Districts to Los Angeles City and Harbor**Standard Oil Co.*

This company owns one 8-in. line, 24 miles long, connecting the Puente Hills district to the refinery at El Segundo, near the coast, about 15 miles southwest from Los Angeles. This line has an estimated capacity of 9,000 barrels per day.

*Southern Pacific Railroad Co.**Amalgamated Oil Co.*

The Los Angeles fields are connected to a refinery near the city of Los Angeles by a pipe line having an estimated capacity of 9,000 barrels per day.

Union Oil Co

	Barrels
One 8-in. line 30 miles long from Puente Hills to Los Angeles harbor.	
One 6-in. line 25 miles long from Puente Hills to Los Angeles harbor, estimated daily capacity.....	45,000

*Summary of Pipe-line Transportation in California Controlled by the
Different Companies*

Standard Oil Co.

		Barrels	
Valley districts.....	60,000		
Coast districts:			
Santa Maria.....	20,000		
Santa Clara valley.....	1,400		
Puente hills.....	9,000	30,400	90,400

Southern Pacific Co.

Valley districts.....	58,000		
Coast districts:			
Santa Maria.....	22,500		
Los Angeles.....	9,000	31,500	89,500

Union Oil Co.

Valley districts.....	50,000		
Coast districts:			
Santa Maria.....	47,500		
Santa Clara valley.....	3,000		
Puente hills.....	45,000	95,500	145,500

General Petroleum Co.

Midway district.....	30,000

Total daily carrying capacity of all the pipe lines in the State..... 355,400

Railroad Transportation.—Although the bulk of the production of the State is transported through pipe lines, a considerable amount is shipped in tank cars, particularly from the Midway and Kern River districts, to points in the San Joaquin valley, the oil being used chiefly by the railroads. Tank-car transportation is also resorted to in hauling the heavy oil produced in certain areas of the Santa Maria district, and is used to a small extent for transporting minor amounts of oil from practically every field to the markets or refineries.

Nearly all the large marketing companies have their own cars, the Standard Oil Co., which operates in most every district in the United States, owning over 15,000 through its subsidiary, the Union Tank Line Co. The Southern Pacific railroad is equipped with about 5,800 cars; the Atchison, Topeka & Santa Fé railroad with about 4,800; and the San Pedro, Los Angeles & Salt Lake railroad with 260. The Associated Oil Co. has about 340; the Union Oil Co. about 180; the Western Pacific railroad 70; and other smaller concerns own a greater or lesser number

according to their needs. The cars have a capacity of between 200 and 300 barrels, thus necessitating between 150 and 100 tank cars daily to transport as much oil as is carried by an 8-in. pipe line in that time.

Tank-Steamer Transportation.—The transportation of oil in tankers is conducted mainly from San Francisco and Port Harford along the Pacific coast from Chile to Alaska, and to the Hawaiian Islands, Japan, and other countries. The large shipments are made to the States of Oregon and Washington, to Canada, and to Hawaii. The tank steamers are owned by the Standard Oil, Union Oil, and Associated Oil companies, the capacity of the tankers varying between 10,000 and 65,000 barrels, the largest at present being the *Richmond* of the Standard and the *Pectan* of the Union, with an estimated capacity of 65,000 barrels each. The number of oil-carrying vessels and their estimated total capacity, controlled by the three companies at present, is as follows:

	Vessels	Capacity Barrels
Standard Oil Co ^a	33	1,360,000
Union Oil Co.....	17	560,000
Associated Oil Co.....	8	230,000
	58	2,150,000

^a Includes steamers for the transportation of refined products.

OIL IN STORAGE

The following table gives in a condensed form the oil reserves above ground during the last four years. It will be noted that the stocks have increased each year until at present it is estimated that there are over 48,000,000 barrels on hand. This accumulation has been mainly brought about by the "bringing in" of large flowing wells in the Valley fields at a time when the consumption was absorbing only the normal output. As a result, practically all the overproduction at that time had to go into storage.

Oil in Storage in California during last Four Years

	Barrels
1910	33,088,000
1911	44,240,000
1912	47,552,000
1913 ^a	48,000,000

^a Estimated.

STORAGE CAPACITY

In order to store the large overproduction of recent years it has become necessary to provide ample tankage in excess of that required under normal conditions. The storage usually employed is of five differ-

ent types: (1) covered steel tanks; (2) covered reinforced-concrete tanks; (3) covered concrete-lined reservoirs; (4) covered clay reservoirs; (5) open earth reservoirs or sump holes.

The steel tanks in more common use for storing oil in large volumes are those having capacities of 55,000 and 37,000 barrels, with a preference for the larger size. Two 1,000,000-barrel reinforced-concrete tanks were built near the Pacific terminal of the Producers Transportation Co.'s pipe line, the walls being designed to carry all the pressure of the oil content. These tanks were not very economical or successful, one of them partly collapsing when oil was run into it. The most efficient receptacles for storing oil in large amounts are the concrete-lined reservoirs built partly into the ground. The Associated Oil Co. has followed this method of construction with great success. The capacity of these reservoirs varies between 500,000 and 750,000 barrels, the latter figure being found more economical. The Standard Oil Co. has used the covered earth or clay reservoir, varying in capacity from 500,000 to 750,000 barrels, for storing the heavy oil of the Kern River district. It is claimed that considerable oil is lost through seepage in these reservoirs, as there is no very good clay available near the fields to build the impervious inner surfaces. The open sump holes are used mainly as temporary storage, for the settling of the sand in the oil, and in case of the unexpected "bringing in" of a large gusher, as was the case with the Lake View gusher, when it is estimated that over 6,000,000 barrels of oil were stored in open earthen reservoirs at one time.

The storage capacity of the three largest companies in California is estimated to be as follows:

	Barrels
Standard Oil Co.....	30,000,000
Associated Oil Co.....	12,000,000
Union Oil Co.....	6,000,000
	48,000,000

REFINERIES

Standard Oil Co.

Point Richmond Refinery.—This is the largest on the coast, has an estimated daily capacity of 60,000 barrels, and is located on San Francisco bay at the terminal of the Standard Oil Co.'s pipe-line system from the Valley fields. The oil is carried to complete fractionation, the residuum being sold locally or exported for fuel, or run down to asphalt.

El Segundo Refinery.—This refinery is situated on the coast near Los Angeles, and has been in operation but a short time. It handles oil from the Puente Hills and Los Angeles districts to complete fractionation, and has a daily capacity of about 15,000 barrels.

Associated Oil Co.

Avon Refinery.—This plant is located on San Francisco bay, Contra Costa county, and has an estimated daily capacity of 20,000 barrels. Here the oil from the Valley fields is refined to gasoline, No. 1 and No. 2 distillate, kerosene, and asphalt.

Gaviota Refinery.—Located at Gaviota, on the coast, about 40 miles from Santa Maria, for treating the oil from the Santa Maria district, the refined products—gasoline, No. 1 and No. 2 distillate, and kerosene—being sold in nearby towns. It is connected by an 8-in. pipe line with the district, and has a daily capacity of about 8,000 barrels. At present the residuum is used by the railroads as fuel.

Amalgamated Refinery.—This plant is located near the city of Los Angeles, for treating a part of the oil produced in the Salt Lake field and Puente Hills district. It has an estimated capacity of 5,000 barrels.

Union Oil Co.

Avila Refinery.—Located near Port Harford, the Pacific terminal of the Producers Transportation Co.'s pipe line. Here the oils from the Santa Maria district and a small part of the production from the Valley fields are topped. The residuum is shipped in tank steamers with the crude oil of the Independent Producers Agency. This refinery is connected with the Santa Maria district by a 6-in. and an 8-in. pipe line, and has an estimated daily capacity of 12,000 barrels.

Oleum Refinery.—This refinery is located on San Francisco bay, and has an estimated daily capacity of 18,000 barrels of crude oil. Here the oil, mainly from the Valley fields, is fractioned into gasoline, kerosene, lubricants, distillate, and asphaltum.

Bakersfield Asphalt Refinery.—Located between Bakersfield and the Kern River district and having an estimated daily capacity of 67 tons of asphaltum.

Other Refineries

There are about 15 small, independent refineries and topping plants near Los Angeles, about 10 near San Francisco, and others throughout the oil fields of the State. Several asphalt and topping plants are located near Bakersfield, which utilize the heavy oil produced in the Kern River district. One or two topping plants are also located near Santa Maria.

EXPORTS

The total amount of crude oil exported from Pacific ports during 1912 was about 2,300,000 barrels, or about 2.66 per cent. of the total production of the State during that year. The greatest amount, about 927,000 barrels, was exported to Canada; the Hawaiian Islands were second in

importance, with about 875,000 barrels; while about 227,000 barrels were exported to Panama and utilized in the building of the canal. Crude oil was also exported to Alaska, Guatemala, Chile, and some other South American countries, the greater part of the oil being shipped from San Francisco. These figures do not take into account the oil that was shipped from San Francisco, Port Harford or Los Angeles to Puget sound and used in American territory, nor any other trade along the western coast of the United States. Practically all the oil shipped is produced in the Valley fields, being transported to San Francisco bay or to Port Harford. The oil shipped from Los Angeles, amounting to 189,000 barrels, was produced in the Coast fields, although at present some of the oil produced in the Valley fields, as well as a part of the residue from the El Segundo refinery of the Standard, is being piped by the General Pipe Line Co. to Los Angeles and thence exported. Of late, the Royal Dutch-Shell Co. has brought some tank steamers loaded with gasoline from the Orient and returned them with kerosene distilled from California oils. It is very likely that the activities of the Shell Co. will open new markets for the California products.

Exports of Oil and Oil Products from San Francisco and Port Harford during October, 1913

	Crude	Gallons	
Hawaii.....	5,523,000		\$94,400
England.....	330		10
	5,523,330		\$94,410
Illuminating			
Costa Rica.....	1,400		\$148
Guatemala.....	19,000		1,995
Honduras.....	1,300		140
Nicaragua.....	87,302		9,780
Panama.....	2,500		312
Salvador.....	7,751		903
Mexico.....	2,000		225
Chile.....	1,020		107
Colombia.....	450		72
Ecuador.....	2,000		250
Peru.....	3,500		400
China.....	2,297,684		103,396
Dutch East Indies.....	1,606,473		74,451
Hongkong.....	2,004,150		90,186
Japan.....	8,238,584		370,736
French Oceania.....	2,000		270
German Oceania.....	2,425		354
Hawaii.....	49,456		7,606
American Samoa.....	5,092		854
	14,334,087		\$662,185

Lubricating

Canada.....	3,810	\$1,131
Costa Rica.....	363	153
Guatemala.....	200	52
Nicaragua.....	70	29
Salvador.....	1,387	430
Mexico.....	867	160
China.....	6,506	748
British India.....	12,952	1,105
Dutch East Indies.....	12,500	1,063
Hongkong.....	3,000	240
Australia.....	35,833	5,726
French Oceania.....	392	181
German Oceania.....	48	27
Philippine Islands.....	440	100
Hawaii.....	16,240	5,357
American Samoa.....	300	120
	94,908	\$16,622

Gasoline

Costa Rica.....	2,510	\$495
Nicaragua.....	1,785	304
Salvador.....	2,283	504
French Oceania.....	11,020	2,132
Hawaii.....	139,953	19,679
	157,551	\$23,114

Other Distillates

Costa Rica.....	5,550	\$659
Australia.....	30,870	2,748
French Oceania.....	17,737	1,665
	54,157	\$5,072

Fuel Oil

Canada.....	5,040,000	\$90,000
Panama.....	3,780,000	67,500
Salvador.....	1,552	38
Chile.....	6,762,000	120,750
Australia.....	1,914	106
Hawaii.....	24,348	1,736
	15,609,814	\$280,130

Residuum for Fuel

Canada.....	882,000	\$18,270
Chile.....	8,199,996	123,869
Japan.....	1,763,226	31,481
French Oceania.....	10,920	306
Alaska.....	1,680,000	30,000
	12,536,142	\$203,926
Grand Total, all oils.....	48,309,989	\$1,285,459

The shipments of oil and oil products to all foreign countries and to Alaska, Hawaii and the American possessions, during October, 1913, from the customs district of San Francisco, which includes Port Harford, from which point some of the heavy shipments to Spanish-American ports are made, totaled 48,309,989 gal., with a value of \$1,285,459. Some of the Spanish-American shipments have been transferred from Port Harford to Los Angeles since the completion of the General Pipe Line to that city.

GEOLOGIC FORMATIONS OF THE OIL DISTRICTS

Oil is found in commercial quantities at one place or another in California in every important geologic horizon from the Chico or upper Cretaceous to the Fernando or Pliocene, and even to the Quaternary if tar springs and asphaltum deposits are included. The principal formations involved in the geology of the oil fields in order of age, beginning with the oldest, are: Jurassic or pre-Jurassic crystalline rocks; the Franciscan, of probable late Jurassic age; the Knoxville-Chico rocks, of Cretaceous age; the Tejon, of Eocene age; the Sespe, probably of Oligocene age; the Vaqueros and Monterey, of lower Miocene age; the Fernando or equivalent, largely of upper Miocene and Pliocene age; and the Quaternary. The commercial quantities of oil are confined chiefly to the Miocene, although important deposits are found locally from the upper Cretaceous to the Pliocene. The geologic column of the southern California Coast Ranges is shown in the accompanying tabulation. A discussion of each of the principal divisions of this column follows.

Basement Crystalline Complex.—Under this head are grouped the granite, schistose, and strongly metamorphosed crystalline rocks which go to make up the core of many of the Coast Ranges. The granite, schist, and limestone included in this series in the Santa Cruz, Santa Lucia, and adjacent mountains, may possibly be older than the Jurassic. The granitic and crystalline rocks, also included in the same category, but occurring in the ranges farther south, are probably of Jurassic age.

Geologic Formations

Tentative correlation of oil-bearing formations of southern California with the standard geologic section.

Period	Sys-tem	Series	Southern California Section	Estimated Thickness Feet
Cenozoic	Quaternary	Recent Pleistocene.....	Alluvium, San Pedro, Fernando (in part).....	1,000
			Unconformity	
	Tertiary	Pliocene.....	Deadman Island, Fernando (in part) ..	1,000
			Unconformity	
		Upper Mio-cene.....	Etchegoin, Fernando (in part), Jacalitos (in part), McKittrick (in part)...	7,000
			Unconformity	
			Santa Margarita, Jacalitos (in part), McKittrick (in part).....	2,000
			Unconformity	
		Lower Mio-cene.....	Monterey (Puente, Modelo).....	7,000
			Unconformity	
			Vaqueros (Puente in part).....	3,000
			Unconformity	
		Oligocene....	Sespe.....	4,300
Mesozoic	Cretaceous	Upper Cretaceous.....	Chico.....	6,000
			Unconformity	
		Lower Cretaceous.....	Knoxville.....	7,000
	Jurassic?		Unconformity	
			Franciscan.....	12,000
			Unconformity	
Paleozoic	?		Granite.....	?
			Unconformity	
			Black schist, limestone.....	?
			Total.....	59,300

Franciscan or Jurassic Metamorphic Series.—The Franciscan formation usually consists of glaucophane and other schists, quartzite, more or less altered sandstone, and shale, the whole intruded by serpentine and

igneous dikes and masses. It is one of the most widespread formations in the Coast Ranges, occurring from the region of Santa Barbara at least as far north as Humboldt county. With the exception of some unimportant traces of oil found in beds believed to be of Franciscan age in Humboldt county, the formation is not known to carry oil.

Knoxville-Chico Cretaceous Rocks.—The Knoxville-Chico series comprises the Cretaceous rocks of the southern Coast Ranges, and attains a thickness of at least 12,800 ft., and possibly much more, in the Coalinga district. The Cretaceous rocks cover large areas in the Coalinga, McKittrick-Sunset, and Santa Maria districts, and other extensive regions in the Coast Ranges, where they are usually characterized by rugged topography. The lower or Knoxville portion of the series generally consists of hard, dark-colored shale and alternating thin-bedded, hard sandstones and shale. The upper or Chico portion of the series is made up of coarse conglomerate at the base, coarse concretionary sandstone above this, and finally, in the Coalinga district in particular, a series of purple organic shales which yield oil. The nodular or concretionary facies is its most characteristic one. Greenish oil, averaging about 35° Baumé (0.8484 sp. gr.), and containing 3 to 4 per cent. of paraffine wax, is produced in commercial quantities from sandstone layers in the purple upper Chico shale in the Oil City field of the Coalinga district. With the exception of oil from one or two localities in Ventura county, this is the only petroleum in the State carrying appreciable amounts of paraffine. Traces of oil are found in the Cretaceous in Contra Costa county and one or two other localities in the State.

Tejon or Eocene Formation.—The Tejon or Eocene rocks, like the Cretaceous, are widespread over the southern Coast Ranges, and, like the Cretaceous, are relatively negligible as a factor in the production of oil in California. Although the Tejon or Eocene carries unmistakable evidences of petroleum at numerous localities throughout the Coast Ranges, and although many wells have been sunk to tap its oil content, there are at present but few commercially productive wells in California deriving their fluid from this formation. Oil in commercial quantities has been obtained from the Tejon or Eocene in the Coalinga, Midway (Carrizo Plains), Santa Clara Valley (Ventura county) districts, and in Vallecitos, San Benito county. The diatomaceous, or other organic shales of the Tejon, are probably the source of the oil contained in it, and in the case of the Coalinga district, the Tejon is the principal ultimate source of the great deposits of oil which are found there in the Vaqueros and other Miocene formations. Although the past development work has not yielded encouraging results, it is probable that the testing of anticlines or other advantageous structural positions in the Tejon will eventually result in successful wells from this formation.

Sespe or Oligocene Formation.—The formation in the geologic column

of the southern Coast Ranges most nearly corresponding to the Oligocene in the world's geologic series, is one characterized by a peculiar reddish-brown and green sand, and called the Sespe, owing to its important development on Sespe creek in Ventura county. In the Summerland district, where it apparently has its maximum development, the formation reaches 4,300 ft. in thickness. It thins rapidly toward the west, and where last distinguished by its peculiar red and green colors in the western end of the Santa Ynez Range, is but a few hundred feet thick. The marine origin of the Sespe formation, unlike most all the other members of the West Coast Tertiary, has not been established; in fact, it is believed by most students of geology to be a non-marine formation. The Sespe contains, so far as is now known, no fossils by which its age can be conclusively determined, but its stratigraphic position relative to other highly fossiliferous strata locates it definitely in the geologic column. It carries commercial quantities of petroleum at one horizon or another in several localities in Ventura county, the most important of which, so far proved, are those of Sisar canyon and the Big and Little Sespe canyons, where it occurs near the base of the formation, and in the Bardsdale, Montebello, and Torrey Canyon fields, where it occurs near the top. The oil occurs in alternating hard sandstone and shales in all portions of the formation except the extreme top and bottom, where well-developed sands yield the fluid. The oil from the Sespe is usually of an excellent quality, ranging in gravity from 25° to 36° Baumé (0.9032 to 0.8434 sp. gr.). Much heavier oil occurs locally, however, as in certain wells in the Big Sespe canyon.

Vaqueros or Lower Miocene Formation.—The Vaqueros or Lower Miocene, unlike the Sespe, is of widespread distribution, occurring in the Coast Ranges practically from one end of the State to the other. From the region of San Francisco bay southward, to the southern end of San Joaquin valley and the western portion of the Santa Ynez Range, the Vaqueros is characterized largely by sandstones and conglomerates. South of these limits, however, it usually consists of dark-colored shales with alternating thin sands. The formation is most variable in thickness, changing from 200 or 300 ft. to 2,000 or 3,000 ft. in relatively short distances. In the Santa Cruz mountains the maximum thickness is about 3,000 ft., in the Coalinga region about 700 ft., in the Sunset-McKittrick from 60 to 1,000 ft., and in the region of Ventura county and southward, from 3,000 to possibly 5,000 ft. The Vaqueros is one of the most important oil-bearing formations of California, being the principal reservoir in the Coalinga district, and one of the most important sources in the Santa Maria, Puente Hills, and Santa Clara valley districts. In addition, it is possible that commercially important deposits of oil will be found in the Vaqueros in scantily tested portions of the Coalinga, Sunset-McKittrick, and Santa Clara valley districts. In the Coalinga district

the petroliferous Vaqueros beds are well-defined sands from 30 to over 100 ft. in thickness near the bottom of the formation, yielding oil varying from 11° to 27° Baumé (0.9929 to 0.8917 sp. gr.); in the Santa Maria district important deposits of 24° to 26° Baumé (0.9091 to 0.8974 sp. gr.) oil occur in the alternating sand, limestone, and shale beds in the transition zone between the top of the Vaqueros and the bottom of the Monterey; while in the Santa Clara valley and Puente Hills districts the oil is of excellent quality, 25° to 35° Baumé (0.9032 to 0.8485 sp. gr.), and occurs in alternating thin-bedded shales and sands at various points throughout the formation. In the Eureka wells, Santa Clara valley district, the oil is believed to come from well-defined sand beds toward the base of the Vaqueros.

Monterey or Lower Miocene Formation.—The Monterey is considered by far the most important formation in the State as regards the ultimate source of the oil, and it is also one of the most important reservoirs of petroleum. Like the Vaqueros, with which it is usually associated and on which it usually rests conformably, it has a widespread distribution over the southern Coast Ranges. It is characterized above everything else by its diatomaceous composition. Diatoms are microscopic, aquatic plants, having the power of locomotion and consisting of a shell or test of silica and an interior of chlorophyl or green matter, the same as the cells of ordinary plants. It is largely the accumulation of innumerable millions of the minute shells of marine diatoms which form the shales of the Monterey. The oil derived from it is also believed to come from the hydrocarbon chlorophyl of the same organisms. With the exception of the diatoms which form such an important part of the Monterey, this formation is almost barren of fossils. The Monterey attains its maximum development in the Santa Maria and Sunset-McKittrick districts, two of the most important oil regions of the State. Here the Monterey shale, largely of diatomaceous origin, attains a thickness of over a mile. Similar conditions, though less pronounced as to thickness of strata, prevail over many other parts of the Coast Ranges. In general, the shale is soft above and harder, even flinty, toward the bottom of the formation, where thin, hard, impure limestone layers are often interbedded. It is in the lower part of the Monterey, in the alternating limestone, sandstone, and flinty shale layers, that the commercial deposits of oil in the main Santa Maria and Lompoc fields occur.

The Monterey formation, or its equivalent, carries commercially important deposits of oil in the main or Orcutt field and the Lompoc field in the Santa Maria district. The gravity of the oil in the former varies from 18° to 27° Baumé (0.9459 to 0.8917 sp. gr.); in the latter from 12° to 35° Baumé (0.9859 to 0.8485 sp. gr.). In these fields the oil occurs in the interbedded sands or in the interstices and crevices in the fractured flinty shale and hard limestone. In the Modelo Canyon region of the

Santa Clara Valley district the oil, which is of excellent quality, varying from 14° to 32° Baumé (0.9722 to 0.8642 sp. gr.), occurs in coarse sands interstratified with the Modelo (equals Monterey) shales. At other localities the oil occurs in crevices and joint planes throughout a considerable extent of the formation, though such deposits are almost always of little value commercially, owing to the uncertainty of striking impregnated zones, and the low available saturation of these zones when encountered. The Monterey or transition Monterey-Fernando yields important quantities of oil in the fields south of Sulphur mountain, Santa Clara Valley district, and in the Whittier, Brea Canyon, and Fullerton fields, Puente Hills district.

Fernando or Miocene-Pliocene Formation.—After the deposition of the Monterey formation in what is now the Coast Ranges of California, came a marked period of disturbance resulting in the elevation and erosion of the Monterey and older formations. This was followed by a general subsidence. The formations laid down following this post-Monterey subsidence are usually conformable with each other (including everything older than the later Quaternary beds) and for this reason they have been grouped together under the name Fernando in the Coast Counties districts. The Fernando and its equivalent post-Monterey formations contain the most important oil reservoirs in the State, this important fact being due in great measure to the unconformable position which they hold to the underlying Monterey shale which is the ultimate source of the oil over so much of the State. More strictly speaking, one should say that the basal portion of the Fernando is the important part, as the upper portion and its equivalents are not commercially oil-bearing so far as known. In general, the Fernando sediments consist of more or less incoherent conglomerates and sands, clayey shales, and soft clays. The Fernando and its equivalents are thick, aggregating from 3,000 to 10,000 ft. in each of the various sections. Among the fields which obtain their oil from the Fernando or its equivalents are the Kern River, Sunset, Midway, McKittrick, Belridge, and Lost Hills (all from the McKittrick formation); San Emidio, a prospective district 20 miles south of Bakersfield (oil sands in Santa Margarita (?) formation); Arroyo Grande and Cat Canyon fields in the Santa Maria district; the Summerland district (main productive area); the Elsmere Canyon field, the field south of Sulphur mountain, the field east of Santa Paula creek, all in the Santa Clara Valley district; the Salt Lake and Western fields, and certain portions of the central and eastern fields in the Los Angeles district; and the Whittier, La Habra, Coyote Hills, Brea Canyon, and portions of the Olinda (Fullerton) fields of the Puente Hills district. With the exception of certain localities in the Sunset, Midway, Belridge, Lost Hills, and some Santa Clara Valley fields, the oil produced by the Fernando is of the fuel type, varying from 11° to 19° Baumé (0.9929 to 0.9396 sp. gr.). The first four mentioned

exceptions yield oil only up to 27° Baumé (0.8917 sp. gr.), while the light oils classified as from the Fernando in the fields south of Sulphur mountain and east of Santa Paula creek, Santa Clara Valley district, are from beds probably transitional Monterey-Fernando. Large deposits of asphaltum, the residuum from oil escaping into the Fernando from the Monterey formation, occur near Arroyo Grande, Sisquoc, Graciosa Ridge, and south of Guadalupe in the Santa Maria district.

San Pedro or Quaternary Formation.—Although not yielding fluid oil in commercial quantities, this, the latest of the California formations, is important from an oil standpoint, as it is the source of commercial deposits of asphalt, the residuum of the oil. The Quaternary deposits usually unconformably overlie the upturned edges of the older formations on the terraces or benches along the coast and important water channels. The deposits are almost always more or less incoherent, generally gravelly or sandy, and are seldom over 30 to 100 ft. thick. Deposits of Quaternary age in the Los Angeles basin and in parts of Ventura county are, however, at least 1,000 ft. thick. The formation is often rich in fossils, most of which are of species still living on the Pacific coast, although in general of a type found in the fauna of Lower California, thus indicating warmer water conditions for the California coast during the Quaternary. The asphaltum deposits and similar indications of petroleum are found, among others, at the following localities: Graciosa ridge and Purisima ridge, Santa Maria district; Santa Barbara and westward along the coast for 20 or 30 miles; Summerland and Carpenteria, Summerland district; Rincon creek and southward, Ventura county; and Newport, Orange county. In the McKittrick district; Sisar Canyon and Sulphur Mountain fields, Santa Clara Valley district; Salt Lake field, Los Angeles district; and Brea Canyon and Olinda fields, Puente Hills district, deposits of asphalt of Quaternary age are found associated with oil sands and oil seepages of the older oil-bearing formations. The deposit on the Rancho la Brea, in the Salt Lake field, near Los Angeles, is noted as containing one of the most important faunas of extinct Quaternary vertebrate animals in the world. This fauna includes mastodons, elephants, lions, saber-toothed tigers, sloths, camels, buffaloes, hyenas, foxes, wolves, bears, horses, and birds and insects, all of which were caught in this great oil or tar spring in past ages.

RELATION OF GEOLOGIC STRUCTURE TO OIL DEPOSITS

Commercial quantities of petroleum occur in practically every form of geologic structure known to the Coast Ranges at one place or another in the California oil fields. When it is remembered that the Coast Ranges of this State afford some most involved folds and faults, complicated by igneous intrusions, the significance of this statement is apparent.

Oil in Anticlines, Monoclines, and Fault Zones.—Among the types of accumulation are those found in both broadly or sharply folded anticlines (Figs. 11 and 13), lying in normal, asymmetric, and overturned positions; in low- and steep-dipping and shouldered or terraced monoclines; in fault zones; and finally, in blocks having little definite structure. The quantity and quality of the oil are usually affected by its relative position in these structures, although in some instances these characteristics remain practically uniform over adjacent structures.

In general, the San Joaquin Valley fields are developed on monoclines (Fig. 2), while anticlines and fault zones are more potent in the fields of the coast counties. In most localities the structure is well exposed at the surface, but in the Salt Lake field of the Los Angeles district, and in one or two other regions, the structure of the oil-bearing formation is entirely blanketed by the Quaternary deposits. It is common to find the structure reflected in the topography, the anticlinal axes, as a rule, following the crests of hills while the more profound valleys occupy the basins of synclines. In the case of asymmetric anticlines and synclines the most important deposits are ordinarily found on the lowest-dipping flank, as evidenced, among other occurrences, by the Coalinga anticline in the Eastside Coalinga field. An exception to the rule is found in the steep-dipping north flank of the Mount Solomon anticline of the Santa Maria field, which yielded more important wells than the lower-dipping south flank.

Oil in Synclines.—Where no water is present in the oil sands and where the axes of the anticlines are not fractured, there is more of a tendency for the oil to collect in synclines than in anticlines. Examples of commercial deposits in synclines are the very important deposits in the Midway Valley syncline, and the equally important ones occurring in the Coalinga syncline between the north end of the Westside field and the Eastside field at Coalinga. Far down on the plunge of both these synclines it is predicted that water will probably be found.

Reservoir for Oil.—Practically all of the wells in California secure their oil from porous marine sedimentary sandstones (Fig. 2). In rare instances, notably in the Santa Maria district, a portion of the oil probably comes from the cracks and interstices in fractured hard flinty shales, or from pores in the softer shales. The character of the sandstone reservoir has a most marked effect upon the accumulation, migration, retention, and quality of the oil; the coarser the sandstone or conglomerate the less will be its normal capacity and the easier the migration of the oil through it, and consequently the quicker will it be drained of its contents. Conversely, very fine sandstones and unfractured shale are slow but persistent producers. Again, other things being equal, the oil in fine sandstones is frequently of lighter quality than that found in adjacent coarser beds. Hard, coherent sandstones generally offer fewer difficulties

in drilling and cause less trouble in the operation of wells than soft or incoherent sands, which often accompany the oil from the well and plug or "sand-up" the hole. On the other hand, where a well which taps a soft sand is enabled through excessive gas pressure to clean itself out during its initial or "flush" flow, the production usually stands up well owing to the favorable conditions produced at the bottom of the hole, where the "blow-out" sand leaves an ideal collecting reservoir for the oil. The famous Lake View gusher and most of the other large producers of the Midway, Sunset, and Coalinga districts might be cited as examples of this kind. A soft sand, however, is not prerequisite for great production, even when the oil occurs in sands, as is evidenced by certain of the large wells of the Eastside Coalinga field and several wells in the Olinda and Brea Canyon fields of the Puente Hills district. Obviously, the thickness of the oil sand or reservoir has an important influence not only on the daily production but on the life of any well. The thicker the sand, other things being equal, the longer the life of the well. This fact accounts for the great staying quality of parts of the Kern River, Coalinga, Santa Maria, Puente Hills, and Santa Clara valley districts. Thin sands, such as encountered in certain areas of the Midway and Sunset districts, though initially most prolific, fall off with alarming rapidity after the first few weeks or months of production.

Capping of the Reservoir.—In practically every field in California the cap-rock or formation immediately overlying the oil reservoir consists of a hard blue or brown shale or clay or hard shell. In rare instances, such as the McKittrick district, and in the Los Angeles field and elsewhere, beds brought into position by horizontal or oblique faulting have acted as efficient barriers to the escape of the oil. Again, in fields where the oil occurs in monoclines with the edges of the oil sands exposed, the hydrocarbons are imprisoned by the residual oil or asphaltum remaining in the oil sand near the surface after the escape of the more volatile constituents. Marked instances of this are to be found in the Whittier field, and in the southeastern end of the McKittrick field, where vertical oil-bearing beds carrying commercial quantities of oil at depths are sealed at the top by asphaltum. The same beds or barriers which prevent the escape of the oils and gases usually prevent the downward migration of water and the dissipation of the former by the latter.

Relation of Water to Oil.—The oil in the California fields, as in most others throughout the world, occurs in inclined or sloping beds of porous sand, and these oil sands are usually overlain and underlain by water sands, which are separated from the oil sands by impervious clay, shale, or other strata. In these two cases the oil is extraneous to the oil sands. These waters are called "top" and "bottom" waters, in accordance with their occurrence, respectively, above or below the oil sands. In a properly finished well the "top" water is cased off or cemented off before the well

is drilled into the oil sand. The "bottom" water is never drilled into except by accident, in which event it is plugged off. With the "top" water shut off and the "bottom" water untouched, the oil is produced practically free from water. Water, being heavier than oil and often also under a greater hydrostatic pressure, will replace part or all of the oil at the point of ingress into the well if it is allowed to reach the oil sand. In this way it replaces the oil, in whole or in part, and thus lessens the amount of oil produced. Water also occurs indigenous to the oil sands in certain fields, but in this case it does not occupy the same part of the stratum as that occupied by the oil, but lies in the lower or "down-slope" portion of the sand, and the line marking the junction of the oil in the "up-slope" part of the bed and the water in the "down-slope" part determines the limits of the productive territory. The water under these conditions is called "edge" water. Upon exhaustion of the oil by flowing or pumping, the "edge" water, through hydrostatic pressure, usually "follows up" and replaces the oil. The appearance of the originally extraneous "top" water or "bottom" water in a well indicates a failure to properly exclude the water by the manipulation of casing, cement, or plugs. Such a condition usually can be remedied and the offending fluid kept out of the oil sand, although what has already come in may sometimes remain in the oil to a greater or lesser extent. The appearance of "edge" water in a well is another matter, for here the oil has been permanently replaced by the water, and so far as the affected sand is concerned, the well can be considered as no longer productive. "Edge" water sometimes appears in a well in some particular sand, while other producing sands are free from water. In this instance the "edge" water sand is abandoned and cased off, and the production continued from the other sands.

In connection with the probable effect of water on oil production, it should be borne in mind that the production of the Kern River field, one of the oldest in the State, is holding up remarkably well, although it is affected by a complication of "top," "bottom," and "edge" waters.

Probably 95 per cent. of the water troubles in the various fields of California is caused by "top" waters which were not shut out of the wells during the drilling process or have broken into the wells since they were finished owing to faulty manipulation or the corroding of the water string of casing. This being the case, many of these troubles are remediable. The question of handling the water is among the most important confronting the California operators to-day.

Origin of the Oil.—The oils of the California fields are believed to have been derived largely from the organic shales which are associated with the oil-bearing beds in all of the fields of the State. It is believed that the oil originated from the organic matter, both vegetable and animal, once contained in these beds. Probably the principal source of the oil has been

the diatomaceous deposits, which make up a large percentage of the Tejon or Eocene formation in the Coalinga district, and the Monterey or lower Miocene formation throughout the balance of the districts. Other organisms that may also be the source of some of the oil are plants, foraminifera, bryozoa, and possibly mollusca and fish. A great deal of evidence can be advanced favoring the organic origin of the oil in California, and enough demonstrating the impossibility of its inorganic origin locally to practically prove the former theory by the process of elimination.

SAN JOAQUIN VALLEY DISTRICTS

COALINGA DISTRICT

This district is the northernmost of the important fields of California, comprising a strip of land about 50 miles in length by 15 miles in width



FIG. 2.—COALINGA DISTRICT.

Outcrop of the main oil sand of the Eastside field, showing the unconformity between the underlying steep-dipping shales and the overlying porous pebbly sand and conglomerate. This sand is very prolific a mile or so down the dip from the outcrop.

along the eastern base of the Coast Ranges. The region is about 55 miles in a straight line from the Pacific ocean, 170 miles southeast of San Francisco, and 200 miles northwest of Los Angeles. The area of the entire district includes about 750 square miles, but the proved oil-bearing

territory only embraces about 35 square miles, or 22,400 acres. It is now the second district in importance in the United States, and the most regular and best understood as regards geologic formations of the principal districts of California. It is accessible by a branch line of the Southern Pacific railroad which connects with the main San Joaquin Valley lines of this road and with that of the Atchison, Topeka & Santa Fé railroad. The pipe lines of the Associated Transportation and Standard Oil companies connect the field with San Francisco. Another Associated line runs to Monterey, and the Producers Transportation Co.'s line connects



FIG. 3.—COALINGA DISTRICT.

Derrick Avenue in Westside field, which is seven miles long and flanked on both sides for the entire distance by producing wells.

the field with Port Harford. Coalinga, the principal source of supplies, is located in Pleasant valley, in the north end of the district, and has a population of about 4,500 people. The main part of the Coalinga district is separated into the Eastside, Westside, and Oil City fields. With the exception of a little oil from the Oil City and Eastside fields, which carries material percentages of paraffine, all of the oil in this district is of asphalt base. The wells in this district vary in depth from 300 to 4,700 ft., the daily production per well ranges from 4 to 3,000 barrels, and the product varies in gravity from 12.4° to 34.5° Baumé (0.9833 to 0.8519 sp. gr.).

Oil City Field.—This field lies on the crest of the Coalinga anticline at the north end of the district and obtains its product from sands in the

upper Chico or Cretaceous formation. The wells vary in depth from 300 to 1,700 ft., penetrate from one to three oil sands with a total thickness of 30 to 95 ft., and yield from 4 to 250 barrels of oil each per day. The oil is greenish in color, 35.5° to 34.5° Baumé gravity (0.8570 to 0.8519 sp. gr.), is characterized by the presence within it of 3 to 4 per cent. of paraffine wax, and is well suited for refining. The first successful work in Coalinga took place in the Oil City field about 1890, shallow wells obtaining a flow of about 10 barrels for a few days from the Chico shale. Desultory prospecting was carried on for a number of years, and in 1895 two wells were drilled which yielded between 15 and 20 barrels of 34° Baumé (0.8536 sp. gr.) oil per day. The development of the Oil City field became more systematic, and during 1896 and 1897 its commercial productivity was completely proved.

Eastside Field.—The Eastside field lies on the crest and east flank of the Coalinga anticline and forms the northeastern portion of the Coalinga district. It obtains its product from sands of Vanqueros or lower Miocene age (Fig. 2). The wells range in depth from 700 to 4,700 ft., penetrate from two to six oil sands with a total thickness varying from 40 to 250 ft., and yield from 30 to 3,000 barrels of oil each daily. The oil varies from greenish to black in color, is of 17.6° to 30.7° Baumé gravity (0.9493 to 0.8718 sp. gr.), and is useful for refining or topping. The development of the Eastside field began in 1900 with the drilling operations of the Independence, Oil City Petroleum, Twenty-Eighth, Caribou, and other companies. The California Oilfields, Ltd., now owns most of the Eastside field.

Westside Field.—The Westside field lies on the western flank (Fig. 3) of the great Coalinga syncline in the western part of the Coalinga district, and obtains its product from the Vaqueros (lower Miocene), Santa Margarita (?), and Jacalitos (upper Miocene). The wells range in depth from 500 to 3,300 ft., penetrate from two to ten oil sands with a total thickness of 25 to 200 ft., and yield from 10 to 2,500 barrels of oil each daily. The oil is black in color, 12.4° to 20° Baumé gravity (0.9833 to 0.9341 sp. gr.), and is used principally for fuel. Oil of 22° to 28° Baumé gravity (0.9210 to 0.8860 sp. gr.), well suited for refining, is obtained in small quantities in the extreme southern end of this field. Successful development work was begun in the northern end of the Westside field in 1901, and by the fall of 1906 the present limits of the field had been practically ascertained.

Prospective Fields.—Test wells have been put down at many points in the Coalinga district, outside the proved area, some obtaining oil, but none being commercially successful. Among the prospective fields partly tested are the Kettleman Hills, Kreyenhagen Hills, and Jacalitos Canyon.

Geology

The formations involved in the geology of the Coalinga district, in the order of their age beginning with the oldest, are: the Knoxville-Chico (Cretaceous); the Tejon (Eocene); the Vaqueros (lower Miocene); and the Santa Margarita, Jacalitos, and Etchegoin (all upper Miocene).

The Knoxville-Chico rocks consist of 12,800 ft. or more of sandstone and shale and form the basement on which most of the oil-producing and oil-bearing beds lie. An oil-bearing sand zone, yielding commercial quantities of oil locally, occurs in the purple shale in the upper part of the Chico in the vicinity of Oil City.

The Tejon consists largely of diatomaceous shales and is believed to be the source of most of the oil in this district. It has a thickness of at least 1,850 ft. on the flanks of Joaquin ridge, and consists of a lower sandy and clayey member of 850 ft. and an upper organic shale member at least 1,000 ft. thick. So far only small quantities of oil have been found in this formation in the Coalinga district, this oil being reported rich in paraffine.

The Vaqueros rests in an unconformable position on the Tejon and underlying formations (Fig. 2), and varies in thickness from 100 ft. in the Westside field to about 700 ft. in the Eastside field. The Vaqueros is the productive formation for the Eastside field and the deeper wells in the Westside field.

The Santa Margarita formation consists of a series of sands and clays with an estimated thickness between 800 and 1,000 ft. in the region of the oil fields proper, and is characterized in the Eastside field by a persistent bed of fine sand and clay about 300 ft. thick, locally called, on account of its peculiar color, the "Big Blue," which forms an effective cap-rock over the Vaqueros oil zone.

The formations above the Santa Margarita, and named in order upward the Jacalitos, Etchegoin, and Tulare (Miocene-Pliocene), consist of clay, sand, and gravel, and are important as affording a covering for the oil-bearing beds below and as carrying water and tar sands in places. The Jacalitos and Etchegoin formations are of upper Miocene age and marine origin; the Tulare formation is of Pliocene age and fresh-water origin.

Structure

All of the formations mentioned are affected in the Coalinga district by the great eastward-dipping monocline which marks the transition between the Coast Ranges and the valley. Subsidiary folds are developed in this monocline, the most important one being the Coalinga anticline, on which the Oil City and Eastside fields are situated. The Westside field covers a strip of land about 1 mile wide and 8 to 9 miles long

following the strike of the monocline. The northern parts of the Westside and Eastside fields are connected, being separated on the south by the intervening Coalinga syncline resulting from the folds just described. The structural conditions affecting the entire district are very uniform, which makes it easy to predict with some degree of accuracy the depth at which the different oil sands will be reached.

Development

The well development in the Coalinga district is summarized in the following table, which indicates the progress in the last four years:

Well Development in the Coalinga District from 1909 to 1913, Inclusive

	Producing Dec. 31	Abandoned During Year	Completed During Year
1909	644	6	88
1910	794	11	148
1911	956	30	192
1912	1042	56	142
1913	911*	....	....

* Estimated for November, 1913.

The wells range in depth from 300 ft. in the Oil City field to over 4,700 ft. on the crest of the plunging Coalinga anticline on the southern limit of the Eastside field. The number of oil sands varies from one to as many as ten, their combined estimated thickness being between 30 and 400 ft.

Production

The following table gives the yearly production of the Coalinga district from beginning to date:

Yearly Production of Coalinga District

Year	Production Barrels	Year	Production Barrels
1896	14,119	1905	10,967,015
1897	70,140	1906	7,991,039
1898	154,000	1907	8,871,723
1899	439,372	1908	10,386,168
1900	532,000	1909	14,795,459
1901	780,650	1910	18,387,750
1902	572,498	1911	18,483,751
1903	2,138,058	1912	19,911,820
1904	5,114,958		
			119,610,520

The following table gives in a condensed form the chemical and physical characteristics of the Coalinga oil.

Physical and Chemical Properties of Coalinga Oils, by Fields

	Color	Baumé at 60° F.	Sp. Gr. at 15° C.	Flash Point, Degrees F.	Calorific Value	Sulphur Per Cent.	Water Per Cent.
Oil City	Greenish	33.5° to 34.5°	0.8570 to 0.8519	Below 53	10,657 to 10,478	0.03 to 0.05	0.0
Eastside	Greenish to black	17.6° to 30.7°	0.9493 to 0.8718	Below 53	10,515 to 10,685	0.35 to 0.60	0.0 to 0.12
Westside, Sec. 6	Black	12.4° to 20°	0.9833 to 0.9341	92 to above 167	10,242 to 10,633	0.47 to 0.77	0.0 to 0.87
Jacalitos	Brownish to Greenish	22° to 28°	0.9210 to 0.8860				
Kreyenhagen:	Greenish	37°	0.8383				
(Vaqueros)	Greenish						
(Tejon)	Black	18°	0.9459				
	Greenish to Black	18° to 37°	0.9459 to 0.8383				

Results of Fractional Distillation of Coalinga Oils, by Fields

	Naphtha (Be- low 150° C.)	Burning Oil (150° to 300° C.)	Lubricating Oil (300° to 400° C.)	Asphaltum (Above 400° C.)	Paraffine Wax	Residue	Loss
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Oil City	26.32 to 29.84	57.72 to 60.30	2.30 to 4.39	1.89 to 8.12	3.54 to 4.47	1.20 to 1.60	1.32 to 3.18
Eastside	0.00 to 13.35	22.20 to 40.85	24.48 to 44.75	8.07 to 36.15		1.42 to 6.89	1.01 to 4.77
Westside	0.00 to 5.14	10.71 to 35.22	23.45 to 46.23	14.30 to 57.42		0.42 to 6.04	0.41 to 3.79

From the foregoing tables it will be noted that the oil from the Oil City wells is characterized by the presence of a small percentage of paraffine wax, something practically unheard of in the California fields except in isolated cases in Ventura county where traces of paraffine occur in certain wells. The Oil City oil is the highest grade oil occurring in commercial quantities in the Coalinga district, being excellent for refining purposes. The great bulk of oil from the Eastside field is also used for refining, or, more properly speaking, for topping, while the Westside oil is practically all of a fuel quality. The oil from wells in Section 6, west of Coalinga, is used for refining, but this excellent quality is very limited in amount.

LOST HILLS DISTRICT

The Lost Hills district is situated about 50 miles southeast of Coalinga in the San Joaquin valley in Kern county. It is the newest of the productive fields, the first well having been drilled in July, 1909. The developed territory extends from Sec. 13, T. 26 S., R. 20 E., to Sec. 9, T. 27 S., R. 19 E., along a narrow strip about 6 miles long and from 1,000 to 2,000 ft. wide. The district is reached from Wasco station on the Santa Fé railroad, and McKittrick on the Southern Pacific railroad, the base of supplies being the town of Wasco, which is connected with the field by good wagon roads. Branch pipe lines of the Producers Transportation, Associated Oil, and Standard Oil companies connect the district with tidewater at Port Harford and San Francisco.

The wells range in depth from 500 to over 2,000 ft. The oil is of asphalt base, with an average gravity of 28° Baumé (0.8861 sp. gr.), and is utilized largely for refining. The gravity of the oil in the north end of the field, where the product comes from the Jacalitos formation, is about 18° Baumé (0.9459 sp. gr.), while that of the oil from the south end, where the product comes from the Santa Margarita formation, averages between 30° and 40° Baumé (0.8750 and 0.8235 sp. gr.).

Geology

The formations involved in the geology of the Lost Hills district, in the order of their age beginning with the oldest, are: the marine Santa Margarita, Jacalitos, and Etchegoin of upper Miocene age, and the Tulare, a fresh-water formation of Pliocene age.

The Santa Margarita consists of a series of diatomaceous shales from 2,000 to 3,000 ft. thick, the entire series being interbedded with fine sandstone and sandy shales. It is believed to be the parent formation of the oil in this district, and the sandy members in the upper part of the formation also act as a reservoir for the oil toward the southern part.

Unconformably overlying the Santa Margarita is a series of blue

clay shales interbedded with bluish sands having a total thickness in this district of over 3,000 ft., the whole believed to be the equivalent of the Jacalitos and Etchegoin formations so well developed in the Coalinga district to the north. The Jacalitos shales form an impervious cover to the underlying oil reservoirs, and where the Santa Margarita is eroded and the oil is allowed passage along the crest of the anticlinal fold, the sands at the base of the Jacalitos become the oil reservoirs. This is the case in the northern part of the district, where the lower sandy members vary between 75 and 100 ft. in thickness, generally in two different bodies.

The Tulare formation, of fresh-water origin, 300 to 500 ft. thick, follows the topography of the region and lies nearly horizontal throughout the Lost Hills district. In the northern part of the field the oil from the underlying formations has migrated upward and collected in the Tulare in minor quantities.

Structure

The dominant structural feature of the Lost Hills district is the well-defined Coalinga anticline, which extends southeastward from Anticline ridge in the Eastside Coalinga field, through the Kettleman hills to the Lost hills, where it runs in a southeast direction, finally plunging under the valley filling with an axial dip of about 150 ft. to the mile. The folding, which has had a controlling influence on all of the formations and on the accumulation and migration of the oil in the district, has been more or less intermittent along the Coalinga anticline, as is attested by the unconformable position of the Jacalitos on the Santa Margarita. The erosion which took place before the deposition of the Jacalitos was more intense toward the northern part of the district, thus exposing lower members of the Santa Margarita formation in this direction. It was from these eroded members that the Santa Margarita oil migrated to the lower sandy beds of the overlying Jacalitos. In the southern part of the district the impervious Santa Margarita shales were not disturbed or eroded to the extent of allowing the escape of the oil, the latter being retained within its sandy members. It will be noted that the gravity of the oil in the Santa Margarita averages about 35° Baumé (0.8485 sp. gr.), while that of the oil in the base of the Jacalitos, presumably also once indigenous to the Santa Margarita, has a gravity of only 18° Baumé (0.9459 sp. gr.).

Development

The wells in the Lost Hills district vary in depth between 600 and 2,000 ft., those obtaining their product from the basal portion of the Jacalitos having a depth of from 500 to 700 ft., while those in the southern part of the productive area and which obtain oil from the sandy members of the

Santa Margarita attain a depth of from 1,200 to 2,000 ft. and over. The yield of the wells producing the heavy oil is close to 100 barrels per day during their early life, while the wells yielding the light oil generally start producing by natural flow as high as a thousand barrels per day. This flush production, however, soon decreases and leaves the well with a daily production at present averaging about 74.8 barrels per day per well, less than that of the more constant wells of heavy oil. The following table indicates the development in this district for the last four years:

Well Development in the Lost Hills District from 1909 to 1912, Inclusive

	Producing Dec. 31	Abandoned During Year	Completed During Year
1909	1	.....	3
1910	2	.....	7
1911	20	6	24
1912	56	15	51
1913*	102	.....	...

* Estimated for November, 1913.

Production

The production of the district during 1912 was 1,367,359 barrels. Previous to this year the yield was included with that of the McKittrick district.

The following analysis gives the composition of typical oils of the Lost Hills District:

Composition of Oils of Lost Hills District

Specific gravity at 77° F.—0.9050, or 24.7° B. (23.6° B. at 60° F.)

		Per Cent.
Gasoline.....	(61° B.—0.7330 sp. gr.).....	2.0
Engine distillate.....	(49.5° B.—0.7800 sp. gr.).....	18.0
Stove distillate.....	(33.6° B.—0.8557 sp. gr.).....	20.0
Fuel oil.....	(25.0° B.—0.9032 sp. gr.)	10.4
Residue.....	(13.4° B.—0.9765 sp. gr.).....	49.6
		100.0

McKITTRICK, MIDWAY, AND SUNSET DISTRICTS

The McKittrick, Midway, and Sunset districts are situated in the southwestern corner of the San Joaquin valley in western Kern county, and include, roughly, about 400 square miles. They are reached by the Sunset Western railroad, a branch line connecting with the main lines of the Southern Pacific and Atchison, Topeka & Santa Fé railroads at Bakersfield, 40 miles to the east. The towns of Maricopa, in the Sunset district, Taft and Fellows, in the Midway district, and McKittrick in the district

of the same name, are the chief centers of distribution of supplies. The pipe lines of the Standard Oil, Associated Oil, General Petroleum, and Producers Transportation companies connect the districts to tidewater.

The topography of these districts is dominated by the Temblor Range, which rises to heights of from 3,000 to 4,000 ft. and bounds them on the west; the San Emidio Range, attaining altitudes of over 8,000 ft., bounds the Sunset district on the south, this district lying in the obtuse angle formed by the junction of the two ranges. In general, the districts may be described as occupying the transition zone of low rolling hills, which is developed between the more or less sharp and rugged topography of the major ranges, and the flats of the San Joaquin valley.



FIG. 4.—McKITTRICK FIELD.

View of north end of field. Note the earthen reservoirs for catching oil and settling the sand. Photograph for U. S. Geological Survey, by R. A.

In November, 1913, there were 311 producing wells in the McKittrick district (includes Belridge), ranging in depth from about 600 to 1,800 ft. The oil in this district is dark colored, varying in gravity from 12° to 20° Baumé (0.9859 to 0.9333 sp. gr.); the production from individual wells ranges from 2 to 1,000 barrels per day. The first recorded commercial production from this district was in 1898, when it is estimated that about 10,000 barrels were produced.

The wells in the Midway district vary in depth from 500 to over 4,000 ft., the product grading from a black oil of 11° Baumé (0.9929 sp. gr.) to a greenish-brown oil of 29° Baumé (0.8805 sp. gr.), and even oil of 36° Baumé gravity (0.8433 sp. gr.) has been reported from certain wells in the Elk and Buena Vista hills. The production of individual wells



FIG. 5.—SUNSET FIELD.

Portion of the developed field. The San Emidio Range appears in the distance on the right. Photograph for U. S. Geological Survey, by R. A.



FIG. 6.—SUNSET FIELD.

Mound of sand and shale "pebbles" that have come with the heavy oil produced. This material greatly hinders the productivity of the wells.

varies from 10 to 2,500 barrels per day, although flush or initial productions have reached 20,000 barrels or more per day. This district, which at present is the most important in the world, is comparatively new, its first yield, less than 5,000 barrels, being recorded in 1901.

The wells in the Sunset district vary in depth between 400 and about 3,000 ft., although unsuccessful wells over 5,200 ft. in depth have been drilled in the region east of the Midway and Sunset producing areas.



FIG. 7.—SUNSET FIELD.

Lake View Gusher in action. At the time when this photo was taken the well was producing about 40,000 barrels per day.

The product of this district varies in gravity from 11° to 21° Baumé (0.9929 to 0.9271 sp. gr.), the production varying from 4 to 300 or 400 barrels, although flush production up to 58,000 barrels per day (Lake View gusher, Fig. 7) has been known in the district. Development work has been carried on in this district for many years, but not until 1900, when it produced somewhat over 12,000 barrels, were the returns commercially profitable.

Geology

The formations involved in the geology of the McKittrick, Midway, and Sunset districts include, in the order of their age beginning with the oldest, coarse, semi-concretionary sandstone 400 ft. or more in thickness, believed to be of Vaqueros or lower Miocene age; 3,000 to 5,000 ft. of siliceous and clayey shale containing numerous thin calcareous layers and concretions of Monterey or lower Miocene age; softer, lighter-colored diatomaceous shale locally silicified to chalcedony, in which are intercalated prominent lenses of coarse granitic sand and conglomerate (the latter containing some boulders up to 6 ft. in diameter), 1,000 to 1,500 ft. thick and believed to be of Santa Margarita or upper Miocene age; a series of 1,200 to 2,000 ft. of soft sands, clays, and conglomerates, probably divisible into more than one stratigraphic horizon, called the McKittrick formation and of upper Miocene and possibly Pliocene age; and, finally, stream deposits, valley fillings and alluvium, of Quarternary age. The Monterey and Santa Margarita formations apparently lie in a conformable series, while the McKittrick (upper Miocene) overlies these unconformably, contains intraformational unconformities, and is, in turn, unconformably overlain by the Quarternary deposits.

The oil is believed to have originated in the diatomaceous shales of the Monterey and Santa Margarita formations, and to have migrated to the porous layers intercalated with them, or to the sands and gravels of the unconformably overlying McKittrick formation. With possibly a few exceptions, the productive sands in all of the operating wells are included in the base of the McKittrick formation or in sands overlying the intraformational unconformity. The deeper sands in some of the wells in the northern part of the Midway district may occur in the Santa Margarita. It is also possible that commercial quantities of oil are contained in sands near the base of the Monterey or in certain structurally favorable localities, particularly in the Sunset district. The geological and structural conditions affecting the accumulation of oil in the Belridge field are somewhat similar to those in the Lost Hills district.

Structure

These districts lie on the northeast flank of the great geoanticline which dominates the Temblor Range. The beds on this flank do not form a simple slope into the San Joaquin valley, but are affected by a series of more or less well-defined folds or anticlines, which in a general way are reflected by hills and ridges on the surface. Such anticlines as the Twenty-five hill and those in the Buena Vista and Elk hills are characteristic of the folds in this region. In general, the dips of the beds on the flanks of these folds are relatively low (5° to 12°) as compared with

those developed in the heart of the Temblor Range, which average over 45°. The largest producers are found on or near the axes of anticlines and subsidiary folds. More water troubles and usually smaller productions are encountered in the wells in synclines.

Broadly speaking, the productive McKittrick district lies on the flanks of three more or less local and highly complex folds subsidiary to the great northeast-dipping monocline. Thrust faulting and overturning have so complicated the folding as to often place the older beds above the younger.

The Midway district is developed on the monocline and on subsidiary folds. The district is divided locally into a number of areas named for topographic or structural features. The most important of these areas are the Buena Vista hills, Midway Flat (valley), Twenty-five hill, Elk hills, etc.

The Sunset district is located on the main monocline and on the Twenty-five and California Fortune anticlines and subsidiary flexures.

McKITTRICK DISTRICT

Location

The McKittrick (Fig. 4) is the northernmost of the districts under discussion, and covers a narrow strip 7 or 8 miles along the foothills immediately west of the town of McKittrick. It includes the newly discovered extension known as the Belridge field, situated 11 miles northwest in an intermediate position between McKittrick and Lost Hills.

Development

The well development in this district is summarized in the following table, which indicates the progress in the last four years:

Well Development in the McKittrick District from 1909 to 1912, Inclusive

	Producing Dec. 31	Abandoned During Year	Completed During Year
1909	208	3	6
1910	231	2	15
1911	246	9	24
1912	297	20	16
1913	311*	....	....

* Estimated for November, 1913.

Production

The following table gives the yearly production of the McKittrick district from beginning to date:

Yearly Production of McKittrick District

Year	Production Barrels	Year	Production Barrels
1898	10,000	1906	531,185
1899	15,000	1907	1,944,671
1900	80,000	1908	2,517,951
1901	430,450	1909	5,077,362
1902	619,296	1910	5,604,653
1903	658,351	1911	5,149,226
1904	400,000	1912	5,881,996
1905	276,171		
			29,196,312

The oil from the wells of this district is black to brownish in color and varies in gravity from 12.5° to 24° Baumé (0.9845 to 0.9091 sp. gr.), the last being unusually light, and, so far as known, produced only by one well. At the north end of the district it ranges between 12.5° and 21° Baumé (0.9845 and 0.9271 sp. gr.), average 15° or 16° Baumé (0.9655 or 0.9589 sp. gr.); the variation in the central part of the district is between 12° and 24° Baumé (0.9859 and 0.9091 sp. gr.), average 15° to 17° Baumé (0.9655 to 0.9524 sp. gr.); the gravity of the oil in the southern end of the district is uniform and of about 18° Baumé (0.9459 sp. gr.), while the gravity of oil from wells in the valley and in the hills north of the McKittrick valley runs from 12° to 14° Baumé (0.9859 to 0.9722 sp. gr.), or possibly a little lighter. The following analysis gives the main physical and chemical characteristics of the average McKittrick product:

Physical and Chemical Properties of Oil from the McKittrick District⁴

Commercial Values

	Average of 26 Samples	Composite Sample
Sp. gr. at 15° C.....	0.9566	0.9600
Degrees Baumé at 60° F.....	16.37	15.83
Heating value:		
Per gram, calories.....	10,282	10,186
Per pound, B.t.u.....	18,508	18,335
Per gallon, B.t.u.....	148,276	146,680
Weight per gallon, pounds.....	8.01	8.00
Flash point (open cup), °C.....	87	74
Burning point (open cup), °C.....	115	109
Viscosity at 20° C. (Engler scale).....	200	160.7
Water, per cent.....	2.0	1.5
Sulphur, per cent.....	0.78	0.74
Naphtha (unrefined), per cent.....	.....	.....

⁴ Allen, Irving C., and Jacobs, W. A.: *Bulletin No. 19, U. S. Bureau of Mines* (1911).

*Physical and Chemical Properties of Oil from the McKittrick
District (Continued)*

Commercial Values

	Average of 26 Samples	Composite Sample
Fuel oil, per cent.....	98.0	98.5
Gasoline (refined), per cent.....	.....	.....
Lamp oil (refined), per cent.....	13.2	14.0
Lubricants (refined), per cent.....	41.0	36.5
Refining losses, per cent.....	6.6	6.1
Distilling losses, per cent.....	0.8	1.2
Asphaltum (commercial), per cent.....	36.4	40.7

Fractional Distillation

Pressure of mercury, millimeters.....	741	735
Water, per cent.....	2.0	1.5
Naphthas:		
Up to 150° C., per cent.....	.....	.....
Unrefined, per cent.....	.....	.....
Lamp oils:		
150° to 175° C., per cent.....	0.1	.....
175° to 200° C., per cent.....	0.4	.....
200° to 225° C., per cent.....	0.9	1.3
225° to 250° C., per cent.....	2.4	3.1
250° to 275° C., per cent.....	3.7	5.0
275° to 300° C., per cent.....	6.8	5.7
Unrefined, per cent.....	14.3	15.1
300° to 325° C., per cent.....	8.9	7.7
Pressure of mercury, millimeters.....	17	20
Lubricants:		
150° to 175° C., per cent.....	0.2	.....
175° to 200° C., per cent.....	1.6	1.6
200° to 225° C., per cent.....	5.4	3.2
225° to 250° C., per cent.....	6.5	6.1
250° to 275° C., per cent.....	6.7	5.8
275° to 300° C., per cent.....	6.8	6.9
300° to 325° C., per cent.....	10.4	10.2
Unrefined, per cent.....	46.5	41.5
Residue (asphaltum), per cent.....	36.4	40.7
Distilling loss, per cent.....	0.8	1.2

MIDWAY DISTRICT

Location

The Midway district embraces the belt of territory about 15 miles long and 10 miles wide extending in a southeasterly direction from about 6 miles southeast of McKittrick to the north limit of the Sunset district,

15 miles southeast. It is separated from the McKittrick district by a strip of unproductive territory, and from the Sunset district by an arbitrary east-and-west line which marks the change from the Mount Diablo to the San Bernardino base and meridian.

Development

The well development in this district is summarized in the following table, which indicates the progress in the last four years:

Well Development in the Midway District from 1909 to 1912, Inclusive

	Producing Dec. 31	Abandoned During Year	Completed During Year
1909	208	....	25
1910	408	12	230
1911	692	46	333
1912	802	92	202
1913	917 ^a	....	.....

^a Estimated for November, 1913.

Production

The following table gives the yearly production of the Midway district from beginning to date:

Yearly Production in Barrels of Midway District

Year	Production Barrels	Year	Production Barrels
1901	4,235	1907	134,174
1902	3,048	1908	410,393
1903	5,000	1909	2,094,851
1904	8,045	1910	10,436,137
1905	11,033	1911	21,196,475
1906 (Included in Sunset)		1912	23,928,368
			58,213,759

The oil from the wells of this district varies from black to brown in color, and in gravity from about 11° to 12° Baumé (0.9929 to 0.9859 sp. gr.) to as high as 25° Baumé (0.9032 sp. gr.). The following analysis gives the main physical and chemical characteristics of the average Midway product:

Physical and Chemical Properties of Oil from the Midway District^a

Commercial Values

	Average of 29 Samples	Composite Sample
Sp. gr. at 15° C.....	0.9570	0.9580
Degrees Baumé at 60° F.....	16.34	16.14
Heating value:		
Per gram, calories.....	10,341	10,314
Per pound, B.t.u.....	18,613	18,565
Per gallon, B.t.u.....	148,345	148,149
Weight per gallon, pounds.....	7.97	7.98
Flash point (open cup), °C.....	78	61
Burning point (open cup), °C.....	99	87
Viscosity at 20° C. (Engler scale).....	518.1	137.9
Water, per cent.....	0.3	0.5
Sulphur, per cent.....	0.83	0.82
Naphtha (unrefined), per cent.....	0.1	.....
Fuel oil, per cent.....	99.6	99.5
Gasoline (refined), per cent.....	0.1	.....
Lamp oil (refined), per cent.....	14.4	15.3
Lubricants (refined), per cent.....	39.7	33.9
Refining losses, per cent.....	6.6	5.8
Distilling losses, per cent.....	0.7	0.7
Asphaltum (commercial), per cent.....	37.8	43.8

Fractional Distillation

Pressure of mercury, millimeters.....	744	739
Water, per cent.....	0.3	0.5
Naphthas:		
Up to 150° C., per cent.....	.....	.....
Unrefined, per cent.....	.....	.....
Lamp oils:		
150° to 175° C., per cent.....	0.4	.....
175° to 200° C., per cent.....	1.0	.....
200° to 225° C., per cent.....	1.3	0.6
225° to 250° C., per cent.....	2.5	3.5
250° to 275° C., per cent.....	4.0	4.9
275° to 300° C., per cent.....	6.8	7.5
Unrefined, per cent.....	16.0	16.5
300° to 325° C., per cent.....	9.0	8.5
Pressure of mercury, millimeters.....	18	20
Lubricants:		
150° to 175° C., per cent.....	0.4	.....
175° to 200° C., per cent.....	2.0	0.9
200° to 225° C., per cent.....	5.0	2.4
225° to 250° C., per cent.....	6.1	4.2
250° to 275° C., per cent.....	6.3	7.1
275° to 300° C., per cent.....	6.7	7.0
300° to 325° C., per cent.....	9.7	8.4
Unrefined, per cent.....	45.2	38.5
Residue (asphaltum), per cent.....	37.8	43.8
Distilling loss, per cent.....	0.7	0.7

^a Allen, Irving C., and Jacobs, W. A., *Bulletin No. 19, U. S. Bureau of Mines* (1911).

SUNSET DISTRICT

Location

The Sunset district (Fig. 5) embraces the territory along the north-eastern base of the Temblor Range, south of the line marking the change from the Mount Diablo to the San Bernardino base and meridian, and includes the southeastern part of T. 12 N., R. 24 W., the northeast part of T. 11 N., R. 24 W., the southwest part of T. 12 N., R. 23 W., and the western part of T. 11 N., R. 23 W.

Development

The well development in this district is summarized in the following table, which indicates the progress in the last four years:

Well Development in the Sunset District from 1909 to 1912, Inclusive

	Producing Dec. 31	Abandoned During Year	Completed During Year
1909	190	2	20
1910	248	4	67
1911	330	7	94
1912	380	32	82
1913	306*	....	....

* Estimated for November, 1913.

Production

The following table gives the yearly production of the Sunset district from beginning to date:

Yearly Production of Sunset District

Year	Production Barrels	Year	Production Barrels
1900	12,500	1907	567,175
1901	188,600	1908	1,556,263
1902	167,558	1909	1,712,771
1903	250,000	1910	7,157,030
1904	276,000	1911	6,350,298
1905	302,701	1912	6,509,093
1906	409,335		
			25,459,324

The hydrocarbon products of the Sunset district consist of heavy tar, oil varying in gravity from 11° to about 20° Baumé (0.9929 to 0.9333

sp. gr.), and gas. The tar occurs in springs along the outcrops of the oil sands in certain exposures of the upturned petroliferous siliceous shales in the southeastern part of the district. The oil is black, and the heavy qualities are very viscous. The heavier oil, averaging from 12° to 13° Baumé gravity (0.9859 to 0.9790 sp. gr.), occurs in the zone just under the tar sands in the shallower wells which are located at either end and along the southwestern edge of the district. The lighter oil, 13.5° to 20° Baumé gravity (0.9756 to 0.9333 sp. gr.), is produced by the deeper wells, especially those in the northern part of the district. The lightest oil occurs in the deeper wells at the northern end of the district. Much sand accompanies the oil (Fig. 6), sometimes as much as two-thirds of the gross yield of the well being sand. One well alone produced over 110,000 cu. ft. of sand in about four years and another has yielded almost as much in two years. The following analysis gives the main physical and chemical characteristics of the average Sunset product:

*Physical and Chemical Properties of Oil from the Sunset District**

Commercial Values

	Average of 25 Samples	Composite Sample
Sp. gr. at 15° C.....	0.9701	0.9705
Degrees Baumé at 60° F.....	14.37	14.26
Heating value:		
Per gram, calories.....	10,266	10,233
Per pound, B.t.u.....	18,478	18,419
Per gallon, B.t.u.....	149,302	149,010
Weight per gallon, pounds.....	8.08	8.09
Flash point (open cup), °C.....	89	71
Burning point (open cup), °C.....	113	101
Viscosity at 20° C., (Engler scale).....	527.2	604.2
Water, per cent.....	1.7	0.4
Sulphur, per cent.....	1.02	1.06
Naphtha (unrefined), per cent.....	0.3	.....
Fuel oil, per cent.....	97.9	99.6
Gasoline (refined), per cent.....	0.3	.....
Lamp oil (refined), per cent.....	8.3	10.7
Lubricants (refined), per cent.....	37.9	32.5
Refining losses, per cent.....	5.8	5.2
Distilling losses, per cent.....	0.7	0.9
Asphaltum (commercial), per cent.....	45.3	50.3

Fractional Distillation

Pressure of mercury, millimeters.....	743	736
Water, per cent.....	1.7	0.4
Naphthas:		
Up to 150° C., per cent.....	0.3	....

* Allen, Irving C., and Jacobs, W. A., *Bulletin No 19, U. S. Bureau of Mines* (1911)

*Physical and Chemical Properties of Oil from the Sunset
District (Continued)*

Fractional Distillation

	Average of 25 Samples	Composite Sample
Unrefined, per cent.....	0.3	....
Lamp oils:		....
150° to 175° C., per cent.....	0.2	....
175° to 200° C., per cent.....	0.6	....
200° to 225° C., per cent.....	0.7	....
225° to 250° C., per cent.....	1.4	1.3
250° to 275° C., per cent.....	2.3	3.4
275° to 300° C., per cent.....	3.8	6.8
Unrefined, per cent.....	9.0	11.5
300° to 325° C., per cent.....	6.6	7.2
Pressure of mercury, millimeters.....	18	20
Lubricants:		
150° to 175° C., per cent.....	0.2	....
175° to 200° C., per cent.....	1.7	0.4
200° to 225° C., per cent.....	4.4	3.1
225° to 250° C., per cent.....	6.3	4.9
250° to 275° C., per cent.....	6.3	5.4
275° to 300° C., per cent.....	7.4	6.2
300° to 325° C., per cent.....	10.2	9.7
Unrefined, per cent.....	43.1	36.9
Residue (asphaltum), per cent.....	45.3	50.3
Distilling loss, per cent.....	0.6	0.9

KERN RIVER DISTRICT

The Kern River district (Fig. 8) lies on the low rolling hills at the foot of the Sierra Nevada which form the eastern rim of the San Joaquin valley. The relief in the immediate vicinity of the field is not sharp, although steep-sided gullies cut the hills in some places. The elevations range from 500 to 1,000 ft. above sea level, the field presenting an undulating appearance. The Kern river, one of the largest in the San Joaquin valley drainage basin, flows south and east of the productive field. A branch of the Southern Pacific railroad penetrates the district and connects with the main line at Oil Junction, about 4 miles to the southwest. The center of supplies is the city of Bakersfield, situated about $4\frac{1}{2}$ miles southwest, with a population of about 12,700 inhabitants. The district is tapped by the pipe lines of the Standard Oil, Associated Pipe Line, and Producers Transportation companies, and most of the oil, although of low gravity, is satisfactorily pumped through pipe lines or shipped in tank cars.

This district is one of the oldest in the State, its discovery in 1899 marking the initiation of the State as a world factor in the production of

fuel oil. During its first productive year the yield of the district amounted to nearly 900,000 barrels, and four years afterward its yearly production was over 18,000,000 barrels. Although no flowing wells were ever struck within its limits, this district is noted for the large amounts of oil that have been recovered from some of the properties. This is due, to a great extent, to the great thickness of the producing sands, which ranges from 200 to 500 ft. This district has produced to date the largest amount of oil of any in the State.

The proved territory has an area of about 15 square miles, having an irregular elliptical form with its longest axis extending in a northwest-



FIG. 8.—KERN RIVER FIELD.

Fully developed area. Wells in this field are placed from 200 to 300 feet apart. One of the large open reservoirs utilized for temporary storage of oil shown in foreground.

southeast direction. The productivity of the wells within this area varies with the distance from the center in a more or less uniform ratio, the more productive wells being located near the central portion. The depth to the productive oil horizons varies from 400 ft. on the northeast rim of the fold to 1,100 or 1,200 ft. on the south and west borders. The average depth of all the wells in the district will approximate 900 ft., and the gravity of the oil produced averages about 14° Baumé (0.9722 sp. gr.). It is used mainly for fuel and the manufacture of asphalt.

Geology

The formations involved in the geology of the Kern River district consist of a basement complex of granitic rocks overlain by a series of

Tertiary sedimentaries which well records show to attain a thickness of about 5,000 ft. in the region of the oil field proper. The granite of the Sierra Nevada is continuous around the south end of San Joaquin valley, and in the vicinity of Kern river the escarpment of the mountain front is believed to mark a normal fault along which the granite on the east has been raised and the Miocene beds on the west depressed.

The Tertiary formations are classed into an upper and a lower division. The upper division is made up of coarse, unconsolidated sands and gravels and contains large quantities of boulders. These beds are supposed to correspond to portions of the Tulare, Etchegoin, and possibly Santa Margarita formations of the western side of the valley. The lower division, composed mostly of clays and soft diatomaceous shales grading up from a basal sandstone, represents the Monterey. The geologic studies so far made tend to show that the major features of Tertiary geologic history were alike on the two sides of the San Joaquin valley. The lower division is regarded as the source of the oil, and the upper as the main zone of its accumulation.

Structure

The structure of this district is that of a low monoclinal dome and presents a symmetrical arrangement as regards its productive territory. Minor folds occur throughout the productive portion of the monocline, and these control, to a certain degree, the extent of local accumulation in the district. The latter, as outlined by drilling, is an ellipse with the production and quality of the oil best immediately northeast of the center and gradually decreasing toward the perimeter.

Development

The following table gives in a condensed form the principal data regarding the operation in this district for the last four years:

Well Development in the Kern River District from 1909 to 1912, Inclusive

	Producing Dec. 31	Abandoned During Year	Completed During Year
1909	1393	22	25
1910	1591	8	22
1911	1787	34	153
1912	1813	68	94
1913	1699*	....	....

* Estimated for November, 1913.

The wells average in depth about 900 ft. and are drilled in about 30 days. The formations penetrated by the wells are sands and clays and contain water-bearing strata above and below the oil-producing zones.

Production

The following table gives the yearly production of this district from beginning to date:

Yearly Production of Kern River District

Year	Production Barrels	Year	Production Barrels
1900	800,000	1907	13,006,136
1901	3,870,170	1908	13,648,286
1902	8,915,801	1909	14,946,784
1903	17,164,549	1910	14,698,907
1904	18,924,000	1911	13,225,713
1905	13,898,062	1912	12,558,439
1906	13,580,334		
			159,237,181

The oil produced in this district is heavy, having an average gravity of 14° Baumé (0.9722 sp. gr.). It is used mainly for fuel, road dressing, and the manufacture of asphalt. The following analysis gives the main physical and chemical characteristics of the average Kern River product:

Physical and Chemical Properties of Oil from the Kern River District¹

Commercial Values

	Average of 40 Samples	Composite Sample
Sp. gr. at 15° C.....	0.9645	0.9670
Degrees Baumé at 60° F.....	15.16	14.78
Heating value:		
Per gram, calories.....	10,307	10,312
Per pound, B.t.u.....	18,553	18,562
Per gallon, B.t.u.....	148,980	149,610
Weight per gallon, pounds.....	8.03	8.06
Flash point (open cup) °C.....	108	102
Burning point (open cup) °C.....	130	128
Viscosity at 20° C. (Engler scale).....	915.6	690.0
Water, per cent.....	0.5	0.5
Sulphur, per cent.....	0.83	0.89
Naphtha (unrefined), per cent.....	.....	.....
Fuel oil, per cent.....	99.5	99.5
Gasoline (refined), per cent.....	.....	.....
Lamp oil (refined), per cent.....	6.6	3.0
Lubricants (refined), per cent.....	39.2	40.9
Refining losses, per cent.....	5.9	5.8
Distilling losses, per cent.....	0.5	0.5
Asphaltum (commercial), per cent.....	47.3	49.3

¹ Allen, Irving C., and Jacobs, W. A.: *Bulletin No. 19, U. S. Bureau of Mines* (1911).

*Physical and Chemical Properties of Oil from the Kern River
District (Continued)*

Fractional Distillation

	Average of 40 Samples	Composite Sample
Pressure of mercury, millimeters	743	741
Water, per cent.....	0.5	0.5
Naphthas:		
Up to 150° C., per cent.....	.....	.....
Unrefined, per cent.....	.....	.....
Lamp oils:		
150° to 175° C., per cent.....	.....	.....
175° to 200° C., per cent.....	0.3	.....
200° to 225° C., per cent.....	0.4	.....
225° to 250° C., per cent.....	0.8	0.5
250° to 275° C., per cent.....	1.6	0.9
275° to 300° C., per cent.....	4.0	1.8
Unrefined, per cent.....	7.1	3.2
300° to 325° C., per cent.....	7.7	4.9
Pressure of mercury, millimeters.....	18	20
Lubricants:		
150° to 175° C., per cent.....	0.1	1.1
175° to 200° C., per cent.....	0.6	2.5
200° to 225° C., per cent.....	2.5	4.1
225° to 250° C., per cent.....	5.8	7.9
250° to 275° C., per cent.....	7.2	9.1
275° to 300° C., per cent.....	8.5	8.3
300° to 325° C., per cent.....	12.2	8.6
Unrefined, per cent.....	44.6	46.5
Residue (asphaltum), per cent.....	47.3	49.3
Distilling loss, per cent.....	0.5	0.5

COAST DISTRICTS

SANTA MARIA DISTRICT

The Santa Maria district (Fig. 9) lies in northern Santa Barbara county, in the region of rolling hills between the Santa Ynez and San Rafael mountains. The district comprises three principal fields, the Santa Maria or Orcutt field, the Lompoc field, and the Cat Canyon field. Up to the present time the greater part of the development has taken place in the Orcutt field, as this was the first one discovered and exploited, the first successful well being finished in August, 1901. The wells in this field yield from 60 to 2,500 barrels of oil per day each, although initial yields of from 2,000 to 12,000 barrels have been recorded. The gravity of the oil varies from 18° to 31° Baumé (0.9459 to 0.8695 sp. gr.). The wells of the Lompoc field yield oil of 16° to 37° Baumé gravity (0.9589 to 0.8383 sp. gr.), varying in amount in the individual wells from 100 to

600 barrels per day. Successful wells were drilled in this field in 1904, and since that time the further development of this part of the district has been assured. In the Cat Canyon field the wells so far brought in have yielded from 150 to as high as 10,000 barrels per day. The quality of the oil in this field runs from 11° to 19° Baumé gravity (0.9929 to 0.9395 sp. gr.).

The center of supplies is the town of Santa Maria, which is connected with Guadalupe, a station on the Coast Line of the Southern Pacific railroad, by an electric railroad. The Pacific Coast railroad connects the different fields with Santa Maria, Port Harford, and San Luis Obispo, this latter city being on the Southern Pacific Coast Line. The greater quantity of the oil produced is piped to the refineries at Gaviota and



FIG. 9.—SANTA MARIA DISTRICT.

View of portion of the Santa Maria or Orcutt field. Photograph for U. S. Geological Survey, by R. A.

Avila on the coast, the Associated Oil Co. owning the former, and the Union Oil Co. the latter plant. The Standard Oil Co., which controls a very small portion of the output, has a pipe line connecting the district with Port San Luis.

Geology

The formations involved in the geology of the productive region of this district include the Monterey (lower Miocene); Fernando (Miocene-Pliocene-Pleistocene); and Quaternary.

The Monterey formation is made up of a 5,000-ft. series of fine shales, largely of organic origin, which overlies conformably the older coarse and

fine sedimentary deposits. These shales are especially important as the probable source of the oil in the district, and the present reservoir in some of the fields, and are characterized by their diatomaceous composition. Although there seems to be perfect conformity throughout the series, it may be divided on lithologic grounds into two parts, a lower one composed chiefly of hard, metamorphosed, in places flinty shales, and an upper one in which soft shale, resembling chalk and giving evidence to the naked eye of its organic origin, is predominant. The oil in the Orcutt and Lompoc fields is derived largely from the basal Monterey beds; the reservoir being interstices in the fractured flinty shales or in fine-grained true oil sands.

The Fernando formation consists throughout of a series of sandstone, conglomerate, and shale resting unconformably upon the Monterey. Unconformities also exist locally within the Fernando. It attains a thickness of at least 3,000 ft. The chief importance of the Fernando in connection with studies of this oil district is derived from the facts that it obscures the oil-bearing formation over a wide area; that it affords through its structure a clue to the structure of the underlying Monterey; and that it acts as a reservoir for the oil in the Cat Canyon field, and as a receptacle for escaping bituminous material in several localities within the district.

Structure

This district is a region of long sinuous folds, a peculiar type of structure characteristic of the Santa Maria region. It is near the axis of these folds that the productive wells are located. In the Santa Maria and Lompoc fields the evidence indicates that anticlinal structure is favorable, although probably not absolutely essential, to the accumulation of oil. Wide, low folds are characteristic of the structure in the Fernando within the Santa Maria basin region. The producing horizons in the Orcutt field are mostly zones of fractured shale or flint offering interspaces, although beds of sand in the Monterey also carry commercial quantities of oil locally. Some of the oil-producing zones are very thick, amounting to hundreds of feet. The oil occurs chiefly in the lower portion of the formation, where brittle, flinty shale is abundant; and it is noticeable wherever these hard, flinty layers appear at the surface that they are usually much more contorted and fractured than the associated softer shales. The wells of the Cat Canyon field probably obtain their product from the basal Fernando or upper Monterey beds along the flanks of low-dipping anticlines.

Development

The well development in this district is summarized in the following table, which indicates the progress in the last four years:

Well Development in the Santa Maria District from 1909 to 1912, Inclusive

	Producing Dec. 31	Abandoned During Year	Completed During Year
1909	220	4	30
1910	241	1	45
1911	255	5	19
1912	249	29	23
1913	240*	..	..

* Estimated for November, 1913.

The wells range in depth from 1,000 to 4,000 ft., the oil being obtained from coarse, hard shale at the base of the Monterey; that of the Cat Canyon from the sandy members near the upper part of the formation.

Production

The following table gives the yearly production of this district from beginning to date:

Yearly Production of Santa Maria District

Year	Production Barrels	Year	Production Barrels
1902	99,288	1908	7,758,579
1903	178,140	1909	7,565,000
1904	669,500	1910	6,947,000
1905	2,560,966	1911	6,630,000
1906	4,692,513	1912	5,909,300
1907	8,651,172		
			51,661,458

This district yields four distinct grades of petroleum in addition to the heavy oil which flows from springs or collects as asphalt deposits. These petroleums vary widely in their physical and chemical properties, and as a consequence are utilized in many different ways, the lighter oils usually for refining, the heavier for fuel, road dressing, etc. The oil as it comes from the wells contains varying quantities of gas, often amounting to a considerable percentage. Some of this gas is very rich in gasoline hydrocarbons, which are removed before utilizing for fuel. The greater portion of the oil is refined at Port Harford and Gaviota. The range in chemical constituents is shown in the following tables.

The oils of the Cat Canyon field range in gravity from 11° to 15.5° Baumé (0.9929 to 0.9622 sp. gr.). The viscosity is high; they are without doubt the most viscous oils produced in California. The yield of asphalt is very high, and the sulphur content of these oils exceeds that of most oils found in the State.

Constituents of Orcutt Field Oil

Sp. gr. (24.1° Baumé).....	0.9084
Color.....	Greenish

		Per cent.
Gasoline.....	(61° B.-0.7330 sp. gr.).....	5.0
Engine distillate.....	(52° B.-0.7692 sp. gr.).....	17.0
Kerosene.....	(42° B.-0.8139 sp. gr.).....	6.0
Stove oil.....	(33° B.-0.8588 sp. gr.).....	23.3
Fuel distillate.....	(29.2° B.-0.8794 sp. gr.).....	16.3
Reduced stock.....	(15.5° B.-0.9622 sp. gr.).....	12.7
Asphalt.....	(grade "D").....	19.7
		100.0

Constituents of Cat Canyon Field Oil

Sp. gr. (14.4° Baumé).....	0.9695
Color.....	Brownish-black

		Per cent.
Gasoline.....	(61° B.-0.7330 sp. gr.).....	None
Engine distillate.....	(52° B.-0.7692 sp. gr.).....	None
Kerosene.....	(42° B.-0.8139 sp. gr.).....	8.0
Stove oil.....	(33° B.-0.8588 sp. gr.).....	24.0
Fuel distillate.....	(29.5° B.-0.8778 sp. gr.).....	18.3
Reduced stock.....	(15.9° B.-0.9596 sp. gr.).....	16.9
Asphalt.....	(grade "D").....	32.8
		100.0

SUMMERLAND DISTRICT

General Statement

The Summerland district owes its importance largely to the fact that its oil is obtained from wells which penetrate sands lying below the Pacific ocean (Fig. 10), and one of the most novel and interesting sights along the coast of California is that of the wharves carrying the derricks which mark the location of these unique wells. The important operations in this district began in 1891, and a maximum of 412 wells have been drilled to date. The district is reached by the Coast Line of the Southern Pacific railroad, and by vessels which touch at the port of Santa Barbara. The town of Summerland, at which is situated the only productive oil field so far developed in the district, lies nearly 6 miles east of Santa Barbara, where practically all the oil is sold, being transported in tank wagons and cars.

The wells range in depth from 100 to more than 600 ft., their initial

production being as high as 100 barrels per day; the average during the most productive years was probably not over 5 barrels per day each. The maximum yield of the district was in 1899, when about 208,000 barrels were produced. The oil is dark brown or black in color and ranges in gravity from 9° to 18° Baumé (1.0071 to 0.9459 sp. gr.), the average being about 14° Baumé (0.9722 sp. gr.), and is used principally for the manufacture of asphalt, for fuel, or for road dressing.



FIG. 10.—SUMMERLAND DISTRICT.

The ocean bluffs in front of Summerland, with wharves and wells. Photograph for U. S. Geological Survey, by G. H. Eldridge.

Geology

The formations involved in the geology of this district include 9,000 ft. of conglomerate, sandstone, and shale of the Tejon or Topatopa (Eocene), and possibly Martinez (lower Eocene); 4,300 ft. of conglomerate, sandstone, and shale of the Sespe, grading conformably into 2,400 ft. of sandstone and shale of the Vaqueros (lower Miocene); 1,900 ft. of shale and volcanic ash of the Monterey (lower Miocene); 1,000 ft. of conglomerate, sandstone, and clay shale of the Fernando (upper Miocene-Pliocene); and 50 ft. of gravel, sand, and clay of the Pleistocene; in all, 18,650 ft. of sediments of Tertiary age. The formations more directly connected with the oil production and accumulation are the Monterey and Fernando.

The Monterey shale, as in many other parts of the Coast Ranges, is here distinguished by its diatomaceous character, and is believed to be the ultimate source of the oil. It has a thickness of at least 1,900 ft. in the Summerland region. Volcanic ash occurs in the Monterey in two zones of 125 ft. and 75 ft. in thickness respectively.

The Fernando in the region east of Santa Barbara consists of clay

and clayey shale, sandstone, and conglomerate. The last two contain oil toward the base of the formation in the Summerland field, and south of the latter, but only in commercial quantities in the developed area. Sandstone and conglomerate with some interbedded clays make up the upper portion of the Fernando, the coarse sediments being composed largely of water-worn Eocene sandstone with scattered pebbles of quartzite and other hard rocks.

Structure

Two local flexures affecting the oil-bearing Fernando formation have been recognized near this district. One of these is a well-developed anticline striking west-northwestward from Loon point, the axis being nearly coincident with the edge of the bluff for more than half a mile northwest of the point. Another flexure, which appears to be a sharp and possibly locally overturned and faulted anticline, striking north of west, occurs in the Fernando beds near the edge of the bluff opposite the Becker and North Star wharves.

The wells of this district for the most part penetrate the beds of the Fernando formation. Those on the terrace in the town, particularly north of the railroad, are drilled in the basal beds of the Fernando; some reach the Monterey shale. The oil is obtained from sands alternating with clay beds in the Fernando formation (upper Miocene or lower Pliocene) which dip almost due south at angles ranging from nearly 90° at the north end of the field to nearly horizontal at the south end. Only one productive sand, from 10 to 45 ft. thick, is penetrated by the terrace wells, but in the wharf wells, two, and in some wells, three oil sands occur.

Development

The following table gives, in a condensed form, the principal data regarding the operation in the district for the last four years:

Well Development in the Summerland District from 1909 to 1912, Inclusive

	Producing Dec. 31	Abandoned During Year	Completed During Year
1909	124	3	..
1910	120	4	..
1911	161	1	42
1912	152	9	..
1913*	122	..	..

* Estimated for November, 1913.

Production

The following table gives the yearly production of the Summerland district from beginning to date:

Yearly Production of Summerland District

Year	Production Barrels	Year	Production Barrels
1894	1,500	1904	119,506
1895	16,904	1905	123,871
1896	39,792	1906	81,848
1897	130,136	1907	56,905
1898	132,217	1908	58,103
1899	208,370	1909	71,189
1900	153,750	1910	71,511
1901	135,900	1911	63,238
1902	143,552	1912	65,376
1903	127,928		
			1,801,594

Water, sludge, and gas accompany the oil in most of the wells of the area. The production ranges from an initial yield of oil containing practically no water to an emulsion containing 98 to 99 per cent. of water.

The color of the oil from the Fernando or main oil zone in this district ranges from the black of the heaviest oil through dark brown to olive brown for the lighter grades. The gravity of the oil ranges from 9° to 18° Baumé (1.0071 to 0.9459 sp. gr.), the average being between 14° and 15° Baumé (0.9722 and 0.9655 sp. gr.). This is classed as among the heaviest oils produced in the State. The viscosity of the average oil in this district is as high as any found in California, being 65 at 15° C. (59° F.) and 3.20 to 3.90 at 85° C. (185° F.) where the viscosity of water equals 1.00. The most prominent chemical characteristics of the Summerland oil are its high percentage of asphaltum, and the absence from it of any gasoline. The range in chemical constituents is shown in the following table:

Constituents of Summerland Oils

Sp. gr. (12.7° to 14° Baumé).....	0.9815	0.9722
Color.....	Black	Black

		Per cent.	
Gasoline.....		Below 150° C.....	0
Engine distillate.. (48° B.-0.7865 sp. gr.)	}	150 to 250° C.....	0.1*
Kerosene..... (41° B.-0.8187 sp. gr.)			3.0
Stove oil..... (33° B.-0.8588 sp. gr.)			4.0
Gas oil..... (28° B.-0.8860 sp. gr.)		250° to 350° C....	16.3
Fuel oil..... (25° B.-0.9032 sp. gr.)			19.1
Lubricants..... (21.5° B.-0.9241 sp. gr.)		350° C.....	20.4
Asphalt..... (grade "D").....			37.1
			98.14 100.0

* O'Neill, Edmond: *Journal of the American Chemical Society*, vol. xxv, pp. 707 to 709 (1903). (Percentage figures after taking out water.)

* Prutzman, P. W.: *Bulletin No. 32, California State Mining Bureau*, p. 194 (1904).

Some analyses show a sulphur content of from $\frac{1}{10}$ to as much as 1 per cent. This is a typical fuel oil, high in asphalt.

SANTA CLARA VALLEY DISTRICT

The Santa Clara valley district is the oldest oil-producing territory in the State, the first oil being obtained about 48 years ago from tunnels driven near Ventura and on the southern flanks of Sulphur mountain.



FIG. 11.—SANTA CLARA VALLEY DISTRICT.

Axis of main anticline in Tar Creek shales, east side of canyon at Pico Canyon wells.
Photograph for U. S. Geological Survey, by R. A.

The first productive well in California was drilled near Ventura in 1867. The district includes the region on either side of the Santa Clara valley from Newhall field in Los Angeles county, 40 miles northwest of the city of Los Angeles, to the Ojai valley field in Ventura county, about 50 miles further west. The Santa Clara valley district produced practically all the oil in the State up to 1880, when the Puente Hills district was discovered. The bulk of the production is of refining grade, its high quality being mainly responsible for the commercial importance of the district. The production of the district in 1912 was 746,780 barrels, most of it being



FIG. 12.—SANTA CLARA VALLEY DISTRICT.
View northwest from Oak Ridge, showing Torrey Canyon wells. Photograph for U. S. Geological Survey, by G. H. Eldridge.



FIG. 13.—SANTA CLARA VALLEY DISTRICT.
Oil wells along the axis of anticline in Modelo Canyon. Photograph for U. S. Geological Survey, by G. H. Eldridge.

transported to seaboard through pipe lines, the oil gravitating from some of the fields to Ventura for a distance of about 50 miles.

This district comprises a number of isolated small fields which derive their production under most peculiar conditions. Some are located in almost inaccessible places, the productive territory being sometimes confined to a very narrow strip along the crest of a sharp fold. The depths of the wells vary from 200 to 3,700 ft., a large number being less than 1,000 ft. It is estimated that the average depth of the wells throughout the district is somewhat less than for any other district in the State. These fields may be grouped according to their position relative to the Santa Clara valley, as follows:

Fields North of Santa Clara River

Ojai Valley and Sisar Creek

Southern flanks of Sulphur mountain (Aliso-Wheeler, Adams, Salt Marsh)

Sespe fields

Hopper Canyon

Modelo, (Fig. 13)

Fields South of Santa Clara River

Bardsdale

Montebello

Torrey Canyon (Fig. 12)

Eureka Canyon

Pico Canyon

Wiley Canyon

Elsmere Canyon

Simi Valley

} (Fig. 11) Newhall field.

The heaviest oil, ranging from 11° to 16° Baumé gravity (0.9929 to 0.9589 sp. gr.), is found in the Ojai Valley, Hopper Canyon, and Elsmere Canyon fields. Practically all of the other fields yield refining oil ranging from 23° to 38° Baumé gravity (0.9150 to 0.8333 sp. gr.). The wells vary in capacity from an initial flow of 500 to 600 barrels per day, to wells which can be profitably operated for a yield of two barrels per day or even less. It is estimated that the average daily production per well for the entire district in November, 1913, was 6.4 barrels.

The oil is derived from various geologic formations under several conditions of structure. The most important oil-producing horizons are the Sespe, Vaqueros, and Modelo (Monterey), and the commonest structural position of accumulation is in anticlines.

The country is accessible through one of the branches of the Southern Pacific railroad, which extends from Saugus on the main Valley line to Montalvo on the main Coast line from 30 to 90 miles northeast of Los Angeles. Roads extend into the various fields from Santa Paula, Fillmore, Piru, and Newhall, the centers of supply for the region. The Santa Clara valley offers an excellent way for pipe lines through which the oil

gravitates from the various fields to Ventura, whence a considerable part of the product is shipped by boat. The Union and Standard Oil companies own pipe lines down the Santa Clara valley, while several local companies own short lines connecting their properties with the main lines or loading racks on the railroad.

Although practically all the fields have been operated for many years, the territory is by no means all prospected, and additions to the productive areas are being made from time to time.

Geology

The formations involved in the geology of the district include a basement complex of granitic and gneissic rocks, on which the following sedimentaries have been laid down in ascending order: the Tejon (Topatopa); Sespe; Vaqueros; Monterey (Modelo); and Fernando. Oil is found in all of these sedimentaries at one point or another throughout the district.

The Tejon, or Topatopa formation, as it is called locally, is the oldest of the sedimentary series and is of Eocene age. It consists of from 3,000 to possibly 9,000 ft. of alternating shale and hard sandstone and quartzite, and so far has proved to be the least important of the commercially productive oil formations in the district.

The Sespe formation, supposed to be of Oligocene age, and characterized by its reddish color and wide distribution throughout the Santa Clara Valley district, overlies the Topatopa and consists of about 3,500 ft. of alternating hard sand and shale layers. It has yielded oil from 11° to 37° Baumé gravity (0.9929 to 0.8383 sp. gr.), and is the most important producer of oil in this district.

The Sespe formation is conformably overlain by the Vaqueros or lower Miocene, which consists of from 800 to 3,000 ft. of dark-colored organic shale and minor amounts of sandstone. At most localities in this region the sandstone members of the formation carry petroleum, so that the formation, when available to the drill, offers inducements for exploitation, especially when the structural conditions are favorable.

The Monterey series (locally called the Modelo), also of lower Miocene age, overlies the Vaqueros and consists of four principal members, as follows:

	Thickness Feet
1. Lower sandstone.....	300 to 1,500
2. Lower shale.....	400 to 1,800
3. Upper sandstone.....	100 to 900
4. Upper shale.....	200 or more

The lower sandstone yields a high-grade oil in the Modelo Canyon wells, while at other points throughout the series there is evidence of petroleum. The lower shale is an important member, well exposed along Pole and other canyons, where it lies in sharp contrast to the creamy upper Modelo sandstone above it.

The Fernando formation, from 5,000 to 8,000 ft. thick, extending from the upper Miocene to the Quarternary, lies in an unconformable position with relation to the older beds, and is locally largely made up of the water-worn fragments of the latter. It is commonly incoherent, although hard layers of conglomerate or sandstone are sometimes met with. The Fernando carries oil in the Newhall field, in the region east of Piru creek, and at several isolated places along the south side of the Santa Clara river.

Structure

The general structure in this district is dominated by an overturned anticline making up the mountain range north of and paralleling the productive oil fields. The local structure affecting the accumulation of oil in any particular region is very complicated, sharp folds (Figs. 11 and 13), faults, cross-folding and overturning being common. These conditions account for the lack of continuity of the productive areas, particularly north of the river. The structure south of the river is controlled by an asymmetric anticline, the axis of which roughly parallels the Santa Clara valley for 15 miles. The accumulation of oil is by no means uniform throughout this fold, commercial quantities occurring only in certain favorable areas resulting from undulations in the fold itself, such being the case in the Montebello and Bardsdale fields with apparently unproductive local areas between them. Owing to the lack of uniformity in structural and sedimentary conditions, the productive zones are encountered at varying depths and at different horizons, and an exact correlation of the same, even in near-by properties, is, at times, almost impossible. This irregularity accounts also to some degree for the diversity of product obtained, the oil ranging in gravity from 10° to 35° Baumé (1.0 to 0.8485 sp. gr.) and even higher.

Development

The following tables give, in a condensed form, important data regarding the principal fields or groups of wells in this district, and the development which has taken place during the last four years.

It is estimated that the average depth of the producing wells is some-

what less than 1,000 ft. and that about five-sixths of the wells produce oil over 18° Baumé gravity (0.9459 sp. gr.).

<i>North of Santa Clara River</i>		Began Producing
Ojai Valley.....	12° to 18° B., 0.9929 to 0.9459 sp. gr.....	1885
Sisar Creek.....	21° to 27° B., 0.9271 to 0.8917 sp. gr.....	1885
Southern flanks of Sulphur Mountain.....		Tunnels in 1861 Wells in 1875
Sespe fields.....	12° to 34° B., 0.9790 to 0.8536 sp. gr.....	1885
Hopper Canyon.....	14° to 15° B., 0.9722 to 0.9655 sp. gr.....	1887
Modelo.....	26° to 28° B., 0.8974 to 0.8860 sp. gr.....	1898

<i>South of Santa Clara River</i>		
Bardsdale.....	27° to 29° B., 0.8917 to 0.8805 sp. gr.....	1896
Montebello.....	33° to 35° B., 0.8588 to 0.8484 sp. gr.....	1911
Torrey Canyon.....	24° to 30° B., 0.9090 to 0.8750 sp. gr.....	1896
Eureka Canyon.....	26° 0.8974 sp. gr.....	1893
Tapo Canyon.....	21° 0.9271 sp. gr.....	1882
Pico Canyon.....	38° 0.8333 sp. gr.....	1875
Wiley Canyon.....	30° 0.8750 sp. gr.....	1900
Elsmere Canyon.....	14° 0.9722 sp. gr.....	1889
Simi Valley.....	36° 0.8433 sp. gr.....	1912

Well Development in the Santa Clara Valley District from 1909 to 1912, Inclusive

	Producing Dec. 31	Abandoned During Year	Completed During Year
1909	335	9	18
1910	341	1	32
1911	333	9	19
1912	347	11	55
1913*	406	....	....

* Estimated for November, 1913.

Production

The following table gives the estimated production of this district from beginning to date. The figures from 1870 to 1882 represent the total production of the State, and those from 1883 to 1898 include the production of the Puente Hills district, the only other producing region in the State at that time.

Yearly Production of Santa Clara Valley District

Year	Production Barrels	Year	Production Barrels
1870	3,600	1891	323,600
1871	5,200	1892	385,049
1872	6,500	1893	470,179
1873	7,200	1894	524,469
1874	7,700	1895	461,883
1875	8,400	1896	298,866
1876	9,600	1897	631,135
1877	13,000	1898	792,990
1878	15,227	1899	729,718
1879	19,858	1900	734,684
1880	40,552	1901	563,127
1881	99,862	1902	584,764
1882	128,636	1903	448,295
1883	142,857	1904	617,770
1884	262,000	1905	437,970
1885	325,000	1906	390,101
1886	377,145	1907	447,223
1887	678,572	1908	469,942
1888	690,333	1909	370,000
1889	303,220	1910	597,000
1890	307,360	1911	620,228
		1912	746,780
			15,097,595

The range in chemical constituents is shown in the following tables:

*Constituents of Santa Clara Valley District Oils¹⁰**Ojai Valley Field*

Sp. gr. (11.8° to 18.8° Baume').....	0.9873	0.9409
Color.....	Black	Black
	Per Cent.	Per Cent.
Engine distillate..... (52° B.-0.7692 sp. gr.)	0	11
Kerosene..... (42° B.-0.8139 sp. gr.)	0	7
Heavy distillate.....	58	59
Asphalt..... (grade "D").....	42	23
	100	100

¹⁰ Prutzman, Paul W.: Petroleum in Southern California, *Bulletin No. 63, California State Mining Bureau*, (1913).

Sespe Field

Sp. gr. (13° to 33.7° Baume').....	0.9790	0.8555
Color.....	Black	Brownish
	Per Cent.	Per Cent.
Gasoline..... (61° B.—0.7330 sp. gr.).....	0	20
Engine distillate..... (52° B.—0.7692 sp. gr.).....	0	10
Kerosene..... (42° B.—0.8139 sp. gr.).....	0	11
Heavy distillate.....	100	44
Asphalt..... (grade "D").....	0	15
	100	100

Torrey Canyon Field

Sp. gr. (23.9° to 29.9° Baume').....	0.9097	0.8756
Color.....	Black	Black
	Per Cent.	Per Cent.
Gasoline..... (61° B.—0.7330 sp. gr.).....	1	17
Engine distillate..... (52° B.—0.7692 sp. gr.).....	6	0
Kerosene..... (42° B.—0.8139 sp. gr.).....	20	15
Heavy distillate.....	53	66
Asphalt..... (grade "D").....	20	17
	100	100

Bardsdale Field

Sp. gr. (19.8° to 27.6° Baumé).....	0.9346	0.8883
Color.....	Black	Black
		Per Cent.
Gasoline..... (61° B., 0.7330 sp. gr.).....		18
Engine distillate..... (52° B., 0.7692 sp. gr.).....		0
Kerosene..... (42° B., 0.8139 sp. gr.).....		17
Heavy distillate.....		33
Asphalt..... (grade "D").....		29
		97

Sisac Creek Valley

Sp. gr. (21.6° B. to 27.3° Baume).....	0.9234	0.8900
Color.....	Brown-black	Brown-black
	Per Cent.	Per Cent.
Gasoline..... (61° B., 0.7330 sp. gr.).....	0	11
Engine distillate..... (52° B., 0.7692 sp. gr.).....	10	13
Kerosene..... (42° B., 0.8139 sp. gr.).....	11	13
Heavy distillate.....	66	50
Asphalt..... (grade "D").....	13	13
	100	100

LOS ANGELES DISTRICT

The Los Angeles district includes the City field (Fig. 14), lying in the city of Los Angeles, and the Salt Lake field, immediately west of the city limits about $4\frac{1}{2}$ miles from its business center. The district lies from 15 to 20 miles from the coast. The Salt Lake field is connected with Los Angeles by a pipe line; the oil from the City field is delivered in tank wagons. The product is sold in Los Angeles and neighboring towns both in a crude and a refined state.

The City field was discovered in 1892 when a 155-ft. shaft was sunk near a small deposit of brea on Colton street. The first successful well was drilled the latter part of 1892 on Second street, and by the end of



FIG. 14.—LOS ANGELES DISTRICT.
Part of City field and City of Los Angeles.

1895 there were more than 300 wells. This field covers a narrow belt about $5\frac{1}{2}$ miles long running through the northern part of the city; the total area is about 2 square miles. The wells vary in depth from 500 to 1,200 ft., the oil produced being between 12° and 19° Baumé gravity (0.9859 and 0.9396 sp. gr.). The limits of the field are well defined; the wells have always been small producers, necessitating pumping, and owing to the great number of wells drilled within such a small area the field has

been drained at a rapid rate and the water allowed to enter the oil sands in many areas. In November, 1913, there were about 420 wells producing an average of about 2.4 barrels per day per well.

The first well in the Salt Lake field was drilled in 1901 by the Salt Lake Oil Co., and since 1902 this field has become the most important in the Los Angeles district. The wells are deeper than in the City field, varying between 1,200 and 3,000 ft., the average gravity of the oil being between 16° and 18° Baumé (0.9589 and 0.9459 sp. gr.). Considerable gas under strong pressure accompanies the oil, which causes the wells to gush during their early life. This gas is used as fuel in the operation of the properties of the field. The limits of this field are ascertained in several directions. It is estimated that there were 290 wells in this field during November, 1913, producing an average of about 23 barrels per day per well.

The discovery of the Los Angeles district marks an important forward step in the fuel-oil industry of the State, this district and Summerland furnishing practically all the fuel oil until the discovery of the Kern River field in 1900.

Geology

The formations involved in the geology of this district consist of the following, in the order of their age beginning with the oldest: more than 2,000 ft. of indurated sandstone, believed to be largely of Vaqueros or lower Miocene age, overlain by about 2,000 ft. of shale and soft, thin-bedded sandstone of Monterey (Puente), also of lower Miocene age; pre-Fernando basalt and diabase intrusions cutting the Monterey; 3,000 ft. or more of soft, thin- and thick-bedded sandstone, thin-bedded shale, and heavy-bedded conglomerate composing the Fernando formation, of upper Miocene and Pliocene age; and a capping of Pleistocene gravels and sands of variable thickness.

The oil in the Los Angeles district is derived largely from the upper 500 ft. of the Monterey and the basal beds of the Fernando.

Structure

The most prominent structural feature in the district is the great flexure in the Vaqueros and Monterey sandstone and shale which lies northeast of the business portion of Los Angeles and trends N. 60° W. This fold is known as the Elysian Park anticline. This anticline might almost be regarded as an elliptical structural dome, as it appears to plunge at both its northwest and southeast ends. Not far from the northwest extremity of the anticline, where it approaches the fault zone lying along the southern base of the Santa Monica mountains, the fold develops into

a fault. The City field is developed in strata at the top of the Monterey and possibly base of the Fernando formations, on the southern limb of the Elysian Park anticline. The trend of the productive belt, however, instead of conforming to the axis of the main fold follows the strike of the formations on the south side of a divergent subordinate line of disturbance, and hence has assumed a direction closely approximating east-and-west. The oil appears to have accumulated in the sands of the southern limb of the anticline just below the point where the steeply dipping beds bend toward the horizontal before passing over the axis of the fold. The structure in the Salt Lake field appears to be that of a minor flexure developed on the flanks of the fold along the southern limb of which the other Los Angeles fields are located.

Development

The well development in the Los Angeles district is summarized in the following table, which indicates the progress in the last four years:

Well Development in the Los Angeles District from 1909 to 1912, Inclusive

	Producing Dec. 31	Abandoned During Year	Completed During Year
1909	697	15	8
1910	703	32	21
1911	701	27	25
1912	699	24	22
1913	710*	....	....

* Estimated for November, 1913.

The wells in the City field range in depth from 500 to 1,200 ft.; those in the Salt Lake field from 1,200 to over 4,000 ft.

Production

The following table gives the yearly production of this district from beginning to date:

Yearly Production of Los Angeles District

Year	Production Barrels	Year	Production Barrels
1894	180,000	1904	1,190,000
1895	729,695	1905	2,672,349
1896	900,000	1906	2,586,779
1897	1,072,000	1907	3,659,088
1898	1,168,000	1908	3,779,311
1899	1,032,036	1909	3,766,415
1900	1,500,000	1910	3,409,000
1901	2,060,000	1911	2,970,000
1902	1,835,000	1912	2,670,463
1903	1,680,000		
			38,860,136

The oils of the City field are uniform in quality, although they vary considerably in gravity. They contain considerable sulphur, and owing to the entire absence of light products are of little value for refining, being used almost entirely for fuel. The oils produced in the Salt Lake field show a marked similarity in general properties, being characterized by a high percentage of sulphur. The heavy oils are highly viscous, and the yield of asphalt is considerable. The following analyses give the composition of typical oils of the Los Angeles district:

*Composition of City Field Oil*¹¹

Sp. gr. (16.5° Baumé).....	0.9557
Viscosity at 185° F.....	2.83 Redwood
Sulphur.....	0.85 per cent. by weight
Thermal value.....	18,787 B.t.u.
Color.....	Brownish black

	Per Cent.
Gasoline..... (61° B.-0.7330 sp. gr.)	None
Engine distillate..... (52° B.-0.7692 sp. gr.)	None
Kerosene..... (42° B.-0.8139 sp. gr.)	None
Stove oil..... (33° B.-0.8588 sp. gr.)	7.0
Middlings and lubricants..... (25° B.-0.9032 sp. gr.)	69.0
Asphalt..... (grade "D")	21.8
Loss and water.....	2.2
	100.0

*Composition of Salt Lake Field Oil*¹¹

Sp. gr. (17.6° Baumé).....	0.9485
Viscosity at 60° F.....	78.63 Redwood
Viscosity at 185° F.....	2.83 Redwood
Flash point.....	Below 60° F., Abel-Pensky test
Color.....	Black

	Per Cent.
Gasoline..... (61° B.-0.7330 sp. gr.)	4.0
Engine distillate..... (52° B.-0.7692 sp. gr.)	6.8
Kerosene..... (42° B.-0.8139 sp. gr.)	6.5
Stove oil..... (33° B.-0.8588 sp. gr.)	4.0
Middlings and lubricants..... (264° B.-0.8951 sp. gr.)	51.4
Asphalt..... (grade "D")	26.8
Loss.....	0.5
	100.0

PUEENTE HILLS DISTRICT

The Puente Hills district is developed along the southern face of the Puente hills, beginning at a point about 12 miles slightly south of east of the city of Los Angeles and extending in a general east-southeasterly

¹¹Prutzman, Paul W.: Petroleum in Southern California, *Bulletin No. 63, California State Mining Bureau* (1913).

direction for 22 miles to Santa Ana river. The hills cover an area, roughly, of about 140 square miles; their western and northern parts lie in Los Angeles county, the southeastern part being divided between San Bernardino county on the north and Orange county on the south. This district is situated but 35 miles from Port Los Angeles, the principal deep-water harbor of southern California, and was the second district discovered in California, the first producing well being finished in 1880. Until 1893 the Puente Hills and Santa Clara valley districts yielded practically



FIG. 15.—PUENTE HILLS DISTRICT.

Whittier oil field, showing development along property lines. Photograph for U. S. Geological Survey, by R. A.

all the oil produced in California. This district comprises the Whittier, Coyote, Puente, and Olinda (Fullerton) fields.

The wells in the Whittier field (Fig. 15) are small producers and range in depth from 600 to 3,500 ft., the average depth being close to 1,650 ft. The oil produced varies between 15° and 24° Baumé gravity (0.9655 and 0.9091 sp. gr.).

The Coyote field is "deep territory," the wells producing large quantities of oil by natural flow. The average depth of the wells is about 3,300 ft., the maximum about 4,500 ft., the oil being between 20° and 33°

Baumé gravity (0.9333 and 0.8589 sp. gr.). The average daily production per well in the Whittier and Coyote fields is at present about 22.8 barrels; that of the Coyote field alone probably several times this, as certain of the wells produce from 1,500 to 3,000 barrels daily.

In the Puente field the first well was drilled in 1880, and wells drilled in the years of 1886 and 1887 are still pumping. The average depth of the wells in this field is somewhat over 1,300 ft.; the average producing life has been about 16 years; the gravity of the oil varies between 21° and 32° Baumé (0.9271 and 0.8642 sp. gr.). At present individual wells yield an average of 1.4 barrels per day.

The Olinda or Fullerton field began producing in 1900. In the Olinda and Brea Canyon areas there is a wide diversity in gravity and output for the different localities. The wells range between 1,500 and 3,500 ft. in depth and produce oil ranging in gravity between 15° and 34° Baumé (0.9655 and 0.8536 sp. gr.). In certain areas great quantities of gas containing commercial quantities of gasoline are produced with the oil, the gasoline being extracted by compression or freezing. The average daily production per well in this field is now about 71.5 barrels.

Geology

The formations involved in the geology of the district include the Puente (Vaqueros and Monterey) formation, largely sandstone and shale of lower Miocene age, and believed to be the ultimate source of the oil in the district; post-Monterey diabase, probably contemporaneous with similar rocks found elsewhere throughout the Coast Ranges; 4,000 ft. of clay, sandstone, and conglomerate of the Fernando formation, largely Pliocene in age; and superficial Pleistocene deposits of sand and gravel. The Puente formation has been divided on lithologic grounds into a lower shale 2,000 ft. thick; a lower sandstone 300 to 1,000 ft. thick; and an upper shale 300 to 400 ft. thick. The lighter grades of oil, such as those produced in the Puente, Olinda, and Brea Canyon fields, are believed to come from the Puente formation, while the heavier grades are derived largely from the coarser sediments of the Fernando.

Structure

The structure of the Puente Hills is that of an anticline, contracted in the western part, expanded in the eastern. The main axis of the flexure is not everywhere easy of recognition, owing to the prominence of nearly parallel secondary folds that exist throughout the length and breadth of the hills. The general and local structure is affected in places by faults of varying intensity. The Coyote hills follow the axis of a well-defined anticline, paralleling the general east-west trend of the Puente hills.

Development

The well development of this district is summarized in the following table, which shows the progress in the last four years:

Well Development in the Puente Hills District from 1909 to 1912, Inclusive

	Producing Dec 31	Abandoned During Year	Completed During Year
1909	422	7	14
1910	431	4	53
1911	454	57	43
1912	470	46	32
1913	499*	..	..

* Estimated for November, 1913.

Production

The following table gives the yearly production of the district from beginning to date:

Yearly Production of Puente Hills District

Year	Production Barrels	Year	Production Barrels
1882-1898	Included with Production under Santa Clara Valley district	1905	2,126,772
		1906	2,804,000
		1907	2,333,000
1899	217,599	1908	4,181,000
1900	511,550	1909	3,963,000
1901	753,198	1910	5,641,165
1902	1,043,463	1911	6,425,000
1903	1,732,153	1912	6,881,650
1904	2,329,655		
			40,943,205

The oil produced varies greatly in composition, the greater portion being of light grade and utilized by refineries near Los Angeles. The following analyses give the physical and chemical characteristics of typical oils of this district, and serve to emphasize the wide range in variation of the different constituents:

*Constituents of Puente Hills District Oils.¹²**Whittier Field*

Color.....	Brown-black	Green-black
Gravity (14.2° to 23.1° Baumé).....	0.9709	0.9144
Sulphur, per cent.....	0.9	0.7
	Per Cent.	Per Cent.
Gasoline..... (61° B., 0.7330 sp. gr.).....	0	8.0
Engine distillate.... (52° B., 0.7692 sp. gr.).....	0	5.0
Kerosene..... (42° B., 0.8139 sp. gr.).....	0	8.0
Heavy distillate..... (28° B., 0.8861 sp. gr.).....	73.0	65.0
Asphalt..... (grade "D")	27.0	14.0
	100.0	100.0

Coyote Field

Color.....	Brown-black	Brownish
Gravity (21° to 30.7° Baumé).....	0.9271	0.8712
Sulphur.....	.....	.....
	Per Cent.	Per Cent.
Gasoline..... (61° B., 0.7330 sp. gr.) .....	.....	9.0
Engine distillate.... (52° B., 0.7692 sp. gr.).....	.....	5.0
Kerosene..... (42° B., 0.8139 sp. gr.).....	.....	17.0
Heavy distillate..... (28° B., 0.8861 sp. gr.).....	.....	43.0
Asphalt..... (grade "D") .....	.....	26.0
		100.0

Puente Field

Color.....	.....	Brown-black
Gravity (21.5° to 32.5° Baumé).....	0.9241	0.8616
Sulphur per cent.....	.....	0.4
	Per Cent.	Per Cent.
Gasoline..... (61° B., 0.7330 sp. gr.).....	0	15.0
Engine distillate.... (52° B., 0.7692 sp. gr.).....	0	13.0
Kerosene..... (42° B., 0.8139 sp. gr.).....	19.0	13.0
Heavy distillate..... (28° B., 0.8861 sp. gr.).....	62.0	46.0
Asphalt..... (grade "D")	19.0	13.0
	100.0	100.0

¹²Prutzman, Paul W.: Petroleum in Southern California, *Bulletin No. 63, California State Mining Bureau*, (1913).

Fullerton Field

Color.....	Black-green	Black
Gravity (15° to 34.5° Baums).....	0.9655	0.8511
Sulphur, per cent.....	1.2	0.4
	Per Cent.	Per Cent.
Gasoline.....(61° B., 0.7330 sp. gr.).....	0	25.0
Engine distillate....(52° B., 0.7692 sp. gr.).....	0	0
Kerosene.....(42° B., 0.8139 sp. gr.).....	4.0	27.0
Heavy distillate.....(28° B., 0.8861 sp. gr.).....	67.0	34.0
Asphalt.....(grade "D")	29.0	14.0
	100.0	100.0

DRILLING METHODS

The drilling methods most commonly employed in California are the standard, rotary, and circulating systems.

With the standard rig the hole is made by the percussion effect of a heavy steel bar suspended from a manila rope or wire line, the motion being imparted by an oscillating beam connected with a steam engine or electric motor. A characteristic of this method is that it necessitates the periodical suspension of drilling in order to remove the accumulated debris, an operation which is greatly facilitated by the water which is let into the well from the strata penetrated or poured into the casing by the drillers.

In the rotary method the hole is made as a result of the abrasive action of a bit or shoe screwed to the end of a revolving column of casing, the debris being removed or washed to the surface and the entire operation greatly facilitated by the action of a stream of water forced through the drill pipe to the space between it and the wall of the hole or to the space between casings. It is therefore apparent that by the use of the rotary method, in certain cases, considerable time is saved over the standard owing to the automatic removal of the drillings.

The circulating system, which has been successfully used, particularly in the Coalinga field, includes the string of tools of the standard and the circulating water arrangement of the rotary. The circulator contains some of the advantages as well as disadvantages of the standard and rotary systems, and in certain territory its use has been found very satisfactory.

As the formations encountered in the different fields vary as to character and thickness, the general use of a single method is out of the question; in fact, two and even the three systems are employed in some fields. In general, it may be said that the standard is used successfully in territory where considerable quantities of hard "shells" are en-

countered, or where conditions are not well known, as in the case of "wild-cat" territory, or in undeveloped properties in productive fields. The standard is also used for finishing some rotary wells, it being considered that there is less chance with the standard tools of missing an oil-bearing bed, by going through it without identification. This system is the one in most general use in California, and has been employed exclusively in the Kern River district, and to a greater or less extent throughout all the fields in the State.

The rotary system is more adapted for drilling through unconsolidated sandstones, clays, and shales, such as are encountered in certain parts of the Sunset-Midway and Coalinga districts. Its use is very efficient in territory where oil or gas is encountered under great pressure, it being a great deal easier to control these large flows by means of the rotary than by the standard or circulating systems. The rotary is most useful where it is possible to land the water string near the oil sand, thus causing a great saving in pipe, as often the well can be finished with two strings instead of four or five, as in the case of standard tools. Some operators claim that by the use of improved drilling bits the field of usefulness of the rotary can be extended to territory where the harder rocks are common.

In certain of the oil districts it has been found economical to drill the unconsolidated sands and clays near the surface with the rotary and finish the well with the standard, a combination rig being employed. The field of usefulness of the circulating system is a matter for careful experimenting, and undoubtedly in many cases this method can replace advantageously either or both the standard and the rotary.

Steam engines generally are used in drilling, although in comparatively shallow wells drilled with the standard rig electric motors have been successfully employed of late. Portable rigs of the standard type are being economically used in some shallow areas in the Lost Hills and Santa Clara valley districts.

Derricks.—In order to place and remove the casing in the well a wooden frame, or derrick, is built over the hole. The derricks vary in height between 87 and 130 ft., the smaller size being used when comparatively shallow wells are drilled by the standard method, the larger size being employed when drilling holes which are expected to attain great depths.

Drilling Lines and Cables.—When drilling by the rotary or circulating systems, the tools are suspended from the walking beam by either a manila cable or a steel wire line. It is customary to employ the cable for the first 1,000 ft. of hole, after which, owing to the buoyancy of the thick cable in the mud-laden water, the cable is replaced by a wire line. The former is from $1\frac{1}{2}$ to $2\frac{1}{2}$ in. in diameter, the lines varying between $\frac{3}{8}$ and $1\frac{1}{4}$ in.

Casing.—In drilling, it is the aim to finish the well with as few strings of casings as possible. Usually the hole is first lined for a few hundred feet with a 16-in. stove-pipe or screw casing, which is employed mainly to hold back the loose surface formation. The hole proper starts with casing having an inside diameter of 12½ in. and continues with 10-, 8½-, and 6½-in. casings, the sizes being reduced with a view to finishing the well with a 6½-in. or larger casing. As water-bearing strata generally occur above, between, or below the oil horizon, and it is of the utmost importance that the water be excluded, it is necessary (even where it is possible to reach the oil sands with the first casing) to utilize one or more strings for shutting off the water before reaching the oil-producing zone. In order properly to exclude the water the cementing process is generally employed. By this method cement is forced between the casing and the wall of the hole. The casings vary in weight from 20 to 70 lb. per foot and are of the screw-joint type in 20-ft. lengths. These are perforated either before being put into the hole or after installation, to admit the inflow of oil and exclude the accompanying sand.

COST OF DRILLING

Owing to the lack of uniformity in the system followed by operators in segregating cost data it is difficult to obtain reliable information regarding the cost of drilling in the different districts. Even when comparing drilling costs on neighboring properties it is necessary to ascertain what items of expense have been included. The following figures represent a rough estimated average of drilling cost in California, the actual cost for individual wells of the depths noted varying at times from 50 per cent. over to 50 per cent. below the average figure given.

Estimated Average Cost of Oil-Well Drilling in California

Depth Feet	Cost
1,000	\$10,000.00
1,500	17,000.00
2,000	25,000.00
2,500	35,000.00
3,000	50,000.00
3,500	70,000.00
4,000	100,000.00

In properties where many wells are drilled, these figures can be reduced materially. For instance, the average cost of drilling wells about 1,000 ft. deep in some properties in the Kern River field varies from \$5,000 to \$6,000; the average cost of a great number of wells about 1,800

ft. deep in the Coalinga and Midway districts being about \$22,000, and that of several wells about 3,100 ft. deep in the Coalinga district about \$44,000.

RECOVERY OF OIL

With the exception of the cases where it reaches the surface by natural flow, the oil in California is pumped by means of a steel-barreled special oil-well pump, screwed at the end of a column of tubing 2 to 3 in. in diameter. These pumps are operated with metal rods, the motion being imparted by means of steam engines, gas engines, pumping powers, or electric motors. The average speed is 20 strokes per minute, the length of the stroke being about 23 in. The estimated maximum capacity, when no gas accompanies the oil, is close to 400 barrels per day. As considerable sand generally accompanies the oil in practically all the fields, a great deal of trouble is occasioned by the wearing of the pump barrels and valves by the sand, and this precludes the use of any but the smooth, tight-fitting steel pumping barrel. In cases where the amount of water in the oil renders the capacity of these pumps insufficient to recover an economical volume of oil the use of the air-lift has been found economical. This method is employed in the Kern River district, and to a lesser degree in other districts. The use of compressed air is also beneficial in special cases, where, owing to peculiar local conditions, the other methods are found uneconomical, as is the case in certain property in the Salt Lake field, where compressed air is used in place of steam to operate steam engines.

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*Table Showing Yearly Production of the Cali-
(Data largely from U. S.*

Year	Santa Maria	Summer land	Santa Clara	Los Angeles	Puente	Coalinga	McKittrick
1865			First tunnel on Sulphur Mt.				
1867			First oil well near Ventura.				
1870			3,600				
1871			5,200				
1872			6,500				
1873			7,200				
1874			7,700				
1875			8,400				
1876			9,600				
1877			13,000				
1878			15,227				
1879			19,858				
1880			40,552				
1881			99,862				
1882			128,636				
1883			142,857				
1884			262,000				
1885			325,000				
1886			377,145				
1887	Only 3 companies in State, operating at Ventura, Pico & Puente.		678,572				
1888			690,333				
1889			803,220				
1890		First well	807,360			First well	
1891			323,600				
1892			385,049				First well
1893			470,179				
1894		1,500	524,469	180,000			
1895		16,904	461,883	729,695			
1896		39,792	298,866	900,000		14,119	
1897		130,136	631,135	1,072,000		70,140	
1898		132,217	792,990	1,168,000		154,000	10,000
1899		208,370	729,718	1,032,036	217,599	439,372	15,000
1900		153,750	734,684	1,500,000	511,550	532,000	80,000
1901	First well	135,900	563,127	2,060,000	753,198	780,650	430,450
1902	99,288	143,552	584,764	1,835,000	1,043,463	572,498	619,296
1903	178,140	127,926	448,295	1,680,000	1,732,153	2,138,068	658,351
1904	669,500	119,506	617,770	1,190,000	2,329,655	5,114,958	400,000
1905	2,560,966	123,871	437,970	2,672,349	2,126,772	10,967,015	276,171
1906	4,692,513	81,848	390,101	2,586,779	2,804,000	7,991,039	531,185
1907	8,651,172	56,905	447,223	3,659,088	2,333,000	8,871,723	1,944,671
1908	7,758,579	58,103	469,942	3,779,311	4,181,000	10,386,168	2,517,951
1909	7,565,000	71,189	370,000	3,766,415	3,963,000	14,795,459	5,077,362
1910	6,947,000	71,511	597,000	3,409,000	5,641,165	18,387,750	5,604,653
1911	6,630,000	63,238	520,228	2,970,000	6,425,000	18,483,751	5,149,226
1912	5,909,300	65,376	746,780	2,670,463	6,881,650	19,911,820	5,881,996

*California Oil Fields. In Barrels (42 Gallons)
Geological Survey.)*

Midway	Sunset	Kern River	Lost Hills	Other Fields	Total Production	Total Value	Avg. Price Per Bbl.	Year
								1865
								1867
					3,600	\$5,125	\$1.420	1870
					5,200	7,370	1.420	1871
					6,500	9,876	1.520	1872
					7,200	10,920	1.515	1873
					7,700	11,540	1.500	1874
					8,400	12,090	1.440	1875
					9,600	15,410	1.605	1876
					13,000	18,140	1.395	1877
					15,227	22,780	1.500	1878
					19,858	29,672	1.495	1879
					40,552	68,450	1.690	1880
					99,862	130,678	1.307	1881
					128,636	172,780	1.340	1882
					142,857	207,540	1.450	1883
					262,000	428,600	1.630	1884
					325,000	613,920	1.885	1885
					377,145	642,785	1.705	1886
					678,572	1,357,144	2.000	1887
					690,333	1,380,666	1.990	1888
					303,220	368,048	1.214	1889
					307,369	384,200	1.250	1890
	First well				323,600	401,264	1.240	1891
					385,049	561,333	1.455	1892
					470,179	608,692	1.294	1893
					705,969	825,983	1.170	1894
					1,208,482	966,785	0.800	1895
					1,252,777	1,180,793	0.944	1896
					1,903,411	1,713,102	0.900	1897
					2,257,207	2,144,346	0.950	1898
		First well			2,642,095	2,615,674	0.990	1899
First well	12,500	800,000			4,324,484	4,108,259	0.950	1900
4,235	188,600	3,870,170			8,786,330	4,973,062	0.566	1901
3,048	167,558	8,915,801			13,984,268	4,873,617	0.348	1902
5,000	250,000	17,164,549			24,382,472	7,399,349	0.303	1903
8,045	276,000	18,924,000			29,649,434	8,265,434	0.279	1904
11,033	302,701	13,898,062		50,563	33,427,273	8,201,846	0.245	1905
	409,335	13,580,334		31,464	33,098,598	9,553,430	0.289	1906
134,174	567,175	13,006,136		77,108	39,748,375	14,699,956	0.370	1907
410,393	1,556,263	13,648,286		88,741	44,854,737	23,433,502	0.522	1908
2,094,851	1,712,771	14,946,784		70,179	54,433,010	30,756,713	0.564	1909
10,436,137	7,157,030	14,698,907	First well	60,405	73,010,560	35,749,473	0.490	1910
21,196,475	6,350,268	13,225,713		20,462	81,134,391	38,719,080	0.477	1911
23,928,368	6,509,093	12,558,439	1,367,359	20,123	86,450,767	39,213,588	0.454	1912



DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at a meeting of the Institute. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y. Unless special arrangement is made, the discussion of this paper will close Apr. 1, 1914.

Cementing Oil and Gas Wells

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(New York Meeting, February, 1914)

Foreword

I HEREWITH present some notes on the use of Portland cement to cement in the casing, and for plugging, to exclude water from oil and gas wells, and the methods employed. I have used my best efforts to make each step of the operation of cementing wells perfectly clear. The information is the result of actual experience and observation. The illustrations are from original drawings made especially for this paper.

Portland Cement

It is not necessary to discuss here the manufacture of cement. Any established brand of the slower setting Portland cements may be purchased with the confidence that it will harden, if properly used, and exclude water from and plug wells efficiently.

Setting.—By the setting of cement is meant its initial change from a soft or plastic mortar to a friable solid. After the cement has become thoroughly set it is still very weak and can be readily pulverized in the fingers. Setting is thought to be effected by the crystallizing out of the silicate and the aluminate of lime, which are soluble in water in their anhydrous form. After dissolving in the water they pass to the hydrated state, in which they are insoluble, and hence are precipitated in a crystalline form.

Ordinarily neat Portland cement mortar remains perfectly plastic for from 1 to 1½ hr. after mixing with water at about 70° F. A higher temperature accelerates and a lower retards setting.

Hardening.—This is due to a continual crystallization of salts from solution, and to further chemical and physical changes which develop slowly, but which continue for long periods of time.

Testing.—It is no more necessary for an operator to go into the scientific testing of cement to be used in a well than to so test the pipe used. He must depend for the quality of each on the tests and reliability of the manufacturer. Cement or pipe may be damaged in shipment so

as to be unfit for use and such damaged material can easily be avoided by proper inspection.

A practical test of cement can be made in advance of its use for this purpose by filling a common galvanized-iron bucket one-third full of water and stirring in neat cement until the mixture is as stiff as it can be made and still be fluid enough to pour or pump. Then fill several tin cans (old fruit cans will do) with the mixture and at once immerse these samples in water. Take out one sample in 24 hr. and examine for set and hardness, another in 48 hr., and so on daily for a week.

Thus a fair idea of how a given cement will act in use may be formed. It is a good plan to take samples, in a similar way, of each batch of cement as run in the well, and place in water. Examinations of such samples from time to time will give a fair idea of how the cement in the well is hardening.

When Cementing is Required

If any formation does not give a satisfactory seat for a casing shoe, a wall packer, or a plug to exclude water from a well it becomes necessary to use a hydraulic cement.

Portland cement mortars are best adapted for the purpose and neat cement only should be used in cementing in casing, for reasons given later.

Initial Rock Pressures

The initial rock pressure of any oil or gas field is in general less than the hydraulic head of 43 lb. per 100 ft. of depth to the productive horizon.

Mud Pressure

Water can easily be ladened with clays so the mud mixture will weigh 33 per cent. more than the same volume of water or give a head of 57 lb. per 100 ft., or a margin of safety of 14 lb. on each 100 ft. of depth over any possible gas pressure or probable water pressure.

Use of Mud in Cementing and Drilling

It is necessary to use a mud mixture in any well to be cemented so as to exclude all oil, gas, or ground water, and such mud is circulated and made to carry the cement to place but not to mix with it.

Mud-ladened water is used in drilling by the hydraulic rotary method to seal off all porous strata immediately as encountered by the drill; also to counterbalance any tendency of ground water, oil, or gas running into the hole.

It is fundamental in drilling by the method mentioned that such mud circulation must go down through the drill pipe and bit and up the walls of the well and overflow to a mud pit at the surface.

Plastic materials such as are cut up by the bit and carried up the hole by the circulation are by the wobble of the drill pipe plastered and rolled into the walls of the well, thus giving any sand strata encountered a plastic covering.

Wells in unconsolidated materials consisting of sand, gravel, mud, and clay skilfully drilled by this method and kept full of mud at all times do not cave when the drill pipe is withdrawn and will remain clear for days so a pipe can be run to bottom without being "pumped down" and the mud circulation restored preparatory to cementing.

There are in very rare cases coarsely porous or cavernous limestones that cannot be mudded off in the usual way.

Capt. A. F. Lucas, in his early experimental drilling in Louisiana and Texas, demonstrated some 15 years ago the use of mud in drilling soft formations to keep the holes in shape and overcome gas and water pressures, and its use became general in the Texas and Louisiana oil fields some 12 years ago, and since in California. I mention this because the use of mud in drilling is now being exploited by the press and magazines as a recent invention of employees of the Bureau of Mines.

Results with the Use of Mud

As a practical matter, drilling with the hydraulic rotary method and using 25 per cent. of mud, I have repeatedly sunk through a gas horizon between 1,500 and 1,600 ft. deep, where there was a measured gas pressure of 650 lb. per square inch, set a screen in this horizon and cemented in a casing above the screen without a bubble of gas showing, and not until the pressure was reduced by bailing of the well did gas show.

Also, by the same method I have drilled through a known artesian water-bearing horizon between 1,900 and 2,000 ft. in depth without any sign of its existence, such as increase in the overflow, or of much loss of mud to the porous strata. In this water well a 6½-in. casing was set at about 1,880 ft. with a rubber wall packer and then drilled to 2,007 ft., when clear fresh water was pumped in through the drill pipe. When the mud was washed out the well began to flow and the drill pipe was withdrawn. This well threw out considerable sand, shells, and pieces of rock, possibly 30 or 40 cu. yd. in two days. In the course of a week the water ran practically clear and reached a steady flow of about 450 gal. per minute at the surface and gave a static head of about 80 ft. It had 80 ft. of surface casing and was then drilled 1,800 ft. without difficulty, passing three known water-bearing horizons and many loose sand beds, but the hole being always kept full of mud did not cave and the drill pipe could be left in over night with no sign of sticking.

Also, wells are frequently drilled into an oil-bearing horizon without showing a sign of oil, the only guide being the known depth to the oil sand in adjacent wells and the taste of oil in the particles of old sand in the overflow.

This brings out the extreme difficulty in prospecting for oil, gas, or water using the hydraulic rotary method of drilling.

Preparation for Cementing in Casing

A well properly drilled by the method before mentioned and kept full of mud is in perfect condition for cementing. Wells drilled by other methods should be lubricated or filled with mud. Before running in the casing it is best to make sure such casing will go to the bottom and turn freely in the hole. This can be done by running in say three joints of the size of casing to be used on a string of drill pipe to the bottom of the hole. It may be necessary to put a rotary shoe on the end of the casing for removing lumps or straightening crooks in the hole. When the pipe is at bottom a proper mud circulation can be established and all water (salt, alkaline, or potable) as well as any oil or gas can be completely excluded and the well brought to condition for successful cementing.

The amount of cement to be provided may be roughly estimated by assuming that one sack (95 lb.) of neat cement mixture will fill 1.25 cu. ft. of space.

If, for instance, an 8-in. pipe is to be set in an 11-in. hole it will take between 20 and 25 sacks of neat cement to fill the calculated space for 100 ft. There should be provided a mixing box about 5 ft. wide by 8 ft. long by 18 in. deep with gate at one end to draw off the mixed cement, two cementing plugs, bottom and top (see Fig. 1), two mortar hoes, four shovels, two galvanized-iron buckets, and a barrel to dip water from; also some sort of screen to pass the dry cement through to break up and take out lumps before mixing. Six men with a box of the size named and with the tools indicated will mix 10 batches of eight sacks each in 1 hr. It is desirable to get the mixed cement in place as quickly as possible and 1 to 1½ hr. is about the limit of time in which cement may be mixed for any one job of casing cementing and run in place. If more than 80 sacks of cement are required, a larger mixing box, or two boxes and more men, or a machine cement mixer will be required.

Mixing Cement Mortars

It is impracticable to specify any particular percentage of water to be used in mixing cement neat or with sand. The best guide is to use the least possible amount of water practical for the work in hand.

As hydraulic cements require water to cause them to set and they will also harden immersed in water it is a common error to suppose they cannot be harmed by an excess of water. Experiments show that any

excess in mixing is weakening in effect and retards setting and hardening. In fact, a large excess of water with prolonged mixing makes a mortar that will not properly harden at all.

If for instance eight sacks of cement are mixed with 18 buckets of water and the mixture works up too thin reduce next batch to say 16 buckets. In all cases make some measure of the water to get a uniform mixture of cement going into the hole.

Methods of Cementing in Well Casing and Plugging Wells

There are several methods of doing this, such as: (1) Lowering the cement mixture in a dump bailer, particularly for plugging wells. (2) Pumping the mixture through a tubing properly arranged to force such mixture outside the casing. (3) Using two cementing plugs and pouring

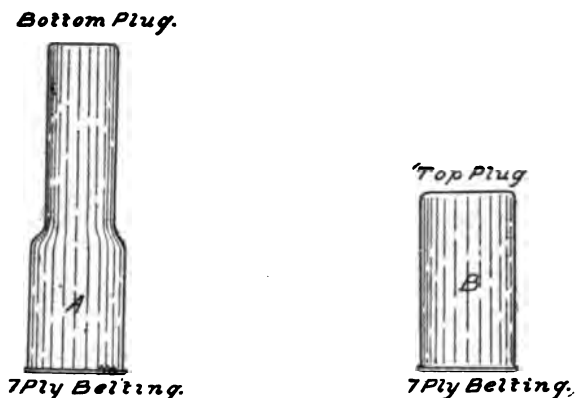


FIG. 1.—CEMENTING PLUGS.

or pumping the mixture in the casing and forcing it down and up outside the casing by pump pressure.

The first method is unreliable and uncertain even in plugging a wet hole. Its use should not be attempted to cement in casing.

The second method is open to the objection of having a string of tubing to manipulate with the casing to be set and as ordinarily used with one cementing plug gives a wet string of tubing (pipe full of water) to pull out.

The third method of using two cementing plugs and displacing the mud with cement by gravity or pumping, as hereinafter described, is in my experience the best for general purposes, as it can be used with the certainty that the cement will be forced by pump pressure into the space between the casing and wall of the well in the shortest possible time and with the least chance of contamination of the cement mixture. There are other methods of cementing with which I am not familiar.

The plugs, Fig. 1, are made of any soft wood that will drill out easily

and of a diameter to pass freely through the pipe in which they are to be used.

The bottom plug (A) should be 30 to 36 in. long, to run in a 6 or 8 in. pipe, and other sizes in proportion. The full-size portion of the plug should be 6 or 8 in. long and the diameter then reduced to 4 or 5 in. for the rest of its length.

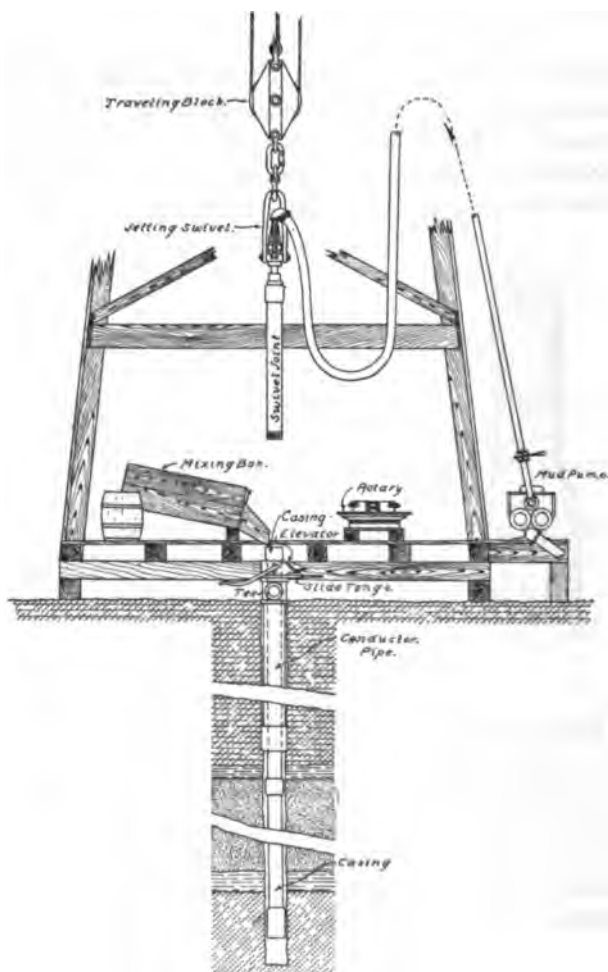


FIG. 2.—INTRODUCING CEMENT BY GRAVITY.

The top plug (B) should be about 8 or 10 in. long for the same sized pipes. Both plugs are faced on the bottom ends with one thickness of 7-ply rubber belting so that they will fit snugly in the casing. These pieces of belting act as scavengers; the one on plug A cleans the inside of the pipe of mud as it descends so as not to adulterate the cement; the one on plug B tends to keep all the cement pushed ahead of it.

Explanation of Cementing Operations

Fig. 2 indicates how the cement may be introduced into the well by gravity. It shows the lower panel of a derrick with mud pump and connections to jetting swivel, also the traveling block. The rotary is set to one side. A conductor pipe is indicated as set in the well with the top coupling replaced with a tee. The overflow from the well may thus be piped through the conductor pipe and tee to the outside of the derrick. In running the casing, as shown, into the well, the cementing plug *A* should be run through each joint as it is hoisted up in the derrick to be connected, in order to make sure that there are no blisters, dents, or other obstructions in them. The casing is lowered to bottom, marked,

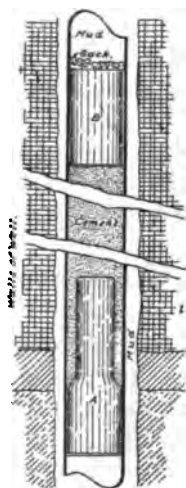


FIG. 3.—CEMENT
BETWEEN PLUGS.
PASSING DOWN
PIPE.

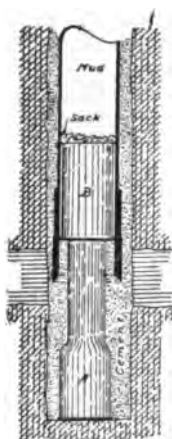


FIG. 4.—CEMENT
IN PLACE. PLUGS
MEET.

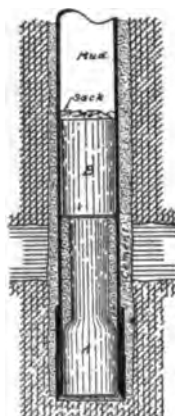


FIG. 5.—CASING
SET ON BOTTOM.
CEMENTING COM-
PLETED.

pulled back just enough so the mud will circulate freely by pumping, and again marked.

After the mud in the well and pit is evenly tempered by circulation, the casing is hung on the slide tongs and elevators placed on the tee on the conductor pipe just under the derrick floor. The swivel joint is unscrewed and set back. In order that the casing will take the cement by gravity the well is bailed down about 200 ft. by displacing the mud with the drill pipe or by bailing in the regular way.

If there is danger in bailing of a gas blow-out or a cave-in from water pressures then other methods must be employed as hereinafter described.

The well and casing should be kept covered at all times so that nothing can fall into the hole. After bailing, the swivel joint is hooked on again and hoisted out of the way to be ready for instant use.

The casing is indicated in the figure in place ready for cementing. The mixing box is placed so that when the end gate is opened the mixed cement will flow into the top of the casing. The water barrel is placed conveniently near and means for filling it quickly must be provided. The cement required should be stacked on the derrick floor and all the necessary tools assembled.

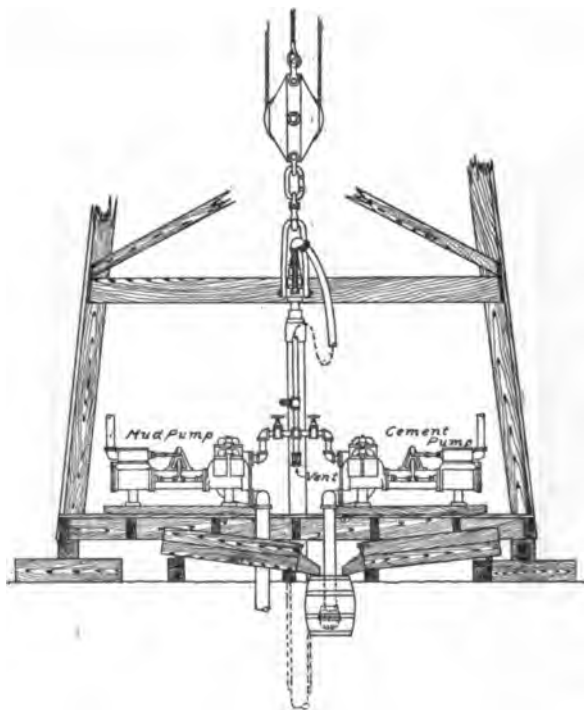


FIG. 6.—INTRODUCING CEMENT BY PUMPING.

The dry cement should be dumped from the sack onto a screen, temporarily placed over the mixing box.

It should not be attempted by this method to put in more than 80 sacks (95 lb. each), as this is about the limit that can be mixed in one hour, with seven men and the appliances mentioned. Everything being ready, the first batch (8 sacks) is mixed, the cover taken off the casing, the plug *A* dropped in small end up, and the cement mixture run in. It is best to pass it through a wire screen ($\frac{3}{8}$ -in. mesh) as it flows into the casing, so as to break up any dry lumps.

The succeeding batches are mixed and run in as rapidly as possible. The neat-cement mixture being much the heavier will force the mud down and then up outside the casing. If the casing is hung up more than 12 or 18 in. from bottom, care must be taken not to push the plug *A* below the casing before being brought to the position as shown in Fig. 4.

The required amount of cement having been put in, the plug *B* is dropped in with a cement sack on it as a packer against the pump pressure, the swivel joint connected, the elevator and slide tongs removed, the casing lowered to 12 or 18 in. off bottom and the mud pump started.

After the mud pump has run long enough to fill the swivel pipe and some pressure is shown by the pump gauge it should be stopped and the vent cock, indicated in Fig. 6, opened to let out the imprisoned air. If air is allowed to remain in the casing, or if the suction pipe of the pump or the piston rod packing leaks, such air becomes highly compressed into bubbles in the mud and may cause trouble. Meantime the mud pit is stirred up to make the descending column of mud as heavy as possible to counterbalance the cement column outside the casing. The number of revolutions required for the pump to fill the casing should be calculated and count kept to anticipate about when the cementing plugs should meet.

The cement column is forced by the pump down the casing between the two plugs as indicated by Fig. 3. When the first plug gets to the bottom of the well it goes partly out of the casing as indicated by *A*, Fig. 4, and allows the cement to pass outward and up between the casing and the walls of the well. The cement floats the mud and it is pushed upward by the pump pressure.

When the plug *B* meets the plug *A*, as indicated in Fig. 4, the cement is all out of the casing and the pump stops short by reason of the plug obstruction and the sack packer. The casing should now be given a few turns in the hole to distribute the cement. This can easily be done by two men with a chain tongs. The pump pressure remains on and the casing is set on bottom as indicated by Fig. 5.

The vent is then opened and there should be only a slight back flow, say a barrel of mud, if all air has been vented at the proper time, and the casing shoe is tight. It will be necessary to hold the pump pressure for 24 hr. if there is a strong back flow.

Objections to Cementing by Gravity

This method requires a reduction of the mud head in the well by bailing and gives opportunity for a gas blow out or for oil or ground waters to enter and cave the well.

Also, the lower end of the casing is open, which may act as a scraper against the walls of the well and the casing may become filled with thick mud enough to prevent the passage of the plugs. It is the practice of some, after a string of casing with the lower end open is run in and the

mud circulation established, to hang up the casing, unscrew the swivel joint, throw in a cement sack and pump it down to make sure the casing is clear before cementing.

If there is no danger in bailing the well down, or in plugging the lower end of the casing with the thick stuff, and 80 sacks or less of cement is to be used, the gravity method is, I think, the best that can be devised.

Necessity of Using Neat Cement

By the means described the neat cement reaches the bottom of the casing with but little if any contamination.

The only means that we have of scavenging the outside of the casing and walls of the well is by floating the mud up and displacing it with the cement mixture.

The heavier the cement the better this action, hence it is desirable to use a cement neat and not reduce it with sand. The cement gets contaminated and mixed to an unknown degree with the mud clinging to the outside of the casing and the walls of the well, which also makes the use of a neat cement practically necessary.

Fig. 6 indicates a general surface arrangement for pumping the cement into the casing. The view is at right angles to that shown in Fig. 2, with two pumps set as commonly used in rotary drilling.

To increase the cement-mixing facilities, two mixing boxes can be used as shown, or a machine mixer employed. The mixed cement is drawn into a barrel, sunk below the surface. The suction pipe of the pump to the right is extended into the cement barrel and the pump to the left has its suction opening in the mud pit (not shown).

The manipulation is the same as in the gravity method of putting in the cement, except that when the plug *A* has been dropped in, the swivel joint is again connected, and the cement pumped in. When the cement is all in, the vent cock is opened; air will be drawn in because the descending column of cement will push ahead the lighter mud and make a vacuum.

The swivel pipe is then disconnected, the plug *B* and sack put in; the pipe is again connected, and the mud pumping started. I usually arrange for the mud pump to discharge into the cement barrel so that the cementing pump will run on mud and thus clean itself and the connections of cement. Since the surface of the cement may fall 100 ft. or more and the casing fill with air when opened, it is essential to vent this air, after the pump gauge shows some pressure, as before described.

Advantages of Pumping Method

By this method no bailing of the well is required, so the danger from blow-outs and cave-ins is eliminated. Also a much larger quantity of cement may be handled in a given time than can be run in by gravity.

Improvement on the Cementing Methods Described

The bottom cementing plug *A* has to pass partly out of the lower end of the casing in order to become operative by the common method and this prevents the use of a back-pressure valve. As the use of such valve together with two cementing plugs was desirable in deep (2,000 ft.) well cementing operations, I invented a method for the simultaneous use of both, as shown in operation in Fig. 7.

This apparatus consists of a double-swedged, by-pass nipple (if for an 8-in. string) made of a piece of 9-in. pipe, about 24 in. long, swedged to 8 in., threaded on both ends and couplings screwed on. Near one end of the 9-in. section two brass bars are put across at right angles, thus forming a rest for the bottom plug, and when the plug is in the position shown the cement is by-passed so the plugs can meet.

The brass bars can be made of $\frac{1}{2}$ -in. brass pipe. They must be substantial, since the pump pressure may rise to 400 lb. and throw 10 tons pressure on them when the plugs meet. A back-pressure valve is screwed into the bottom coupling on the by-pass nipple as shown in Fig. 7. This should be a substantial brass valve for deep work. The bars and valve are made of brass so that they can be easily drilled out, with the wooden plugs, at the proper time.

Under the back-pressure valve is fitted a 9 to 8-in. swedged nipple not threaded on the 9-in. end. This acts as a casing shoe and protects the valve.

The two couplings on the by-pass nipple should be screwed up as tight as possible and then pinned or riveted in each thread. When the wooden plugs, brass bars, valve, and cement are being drilled out there is a possible danger that these threads may work loose by the action of the drill and the parts unscrew. This would make trouble and should be avoided.

Advantage of Using the Double-Swedged Nipple

This invention (not patented) prevents the possible accidental passage of the cementing plugs out of the casing and permits the use of a back-pressure valve. This valve prevents thick mud from being forced back into the casing. The casing can be partly floated, thus making a long string much easier to handle. The casing can be bailed down to take any quantity of cement by gravity without endangering the well, also the cement mixture after passing the valve cannot flow back into the casing. The cementing operation may be done by gravity or pumping as before described.

Setting Screen and Cementing Casing Above

When casing cementing is required, it is usually necessary also to set a screen, to make a proper test for oil or gas or bring a well in from a

known horizon. In such cases I prefer to set a screen the full size of the casing required, for the closer the screen fits to the walls of the well the better for the well.

The screen with two joints of the same size casing above may be run in on a string of drill pipe.

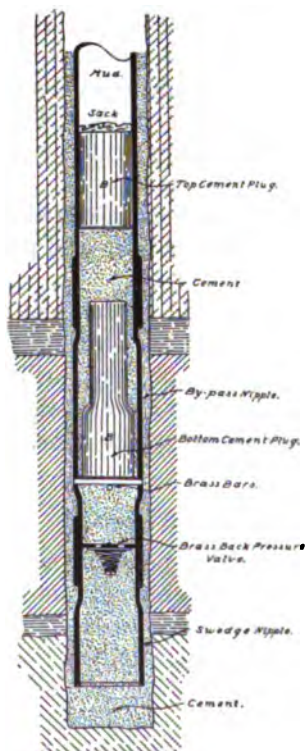


FIG. 7.

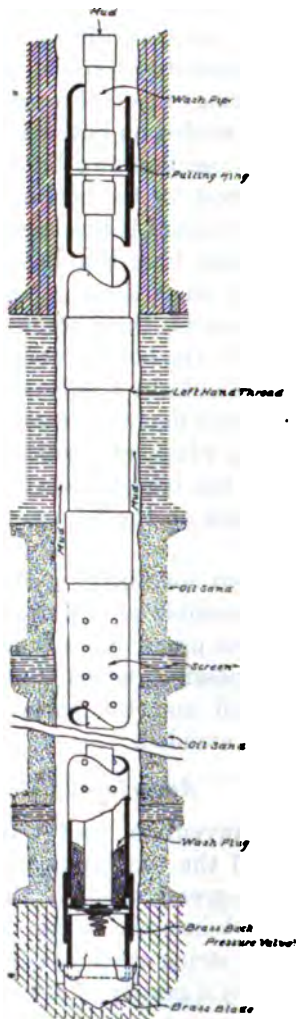


FIG. 8.

Fig. 8 shows a screen set in place with all necessary fitting. The brass blade shown at the very bottom is to produce friction in order that the left-hand thread at the top of the screen may be easily unscrewed at the proper time. The short one-thread nipple is to hold the brass

blade and protect the back-pressure valve. This valve is for the purpose before described and permanently closes the lower end of the screen when set. The wash plug in the lower end of the screen serves as a guide and packer to the wash pipe. The function of the wash pipe is to carry all the mud down through the screen and the back-pressure valve so it may pass up outside the screen and casing.

The screen may be of any size or length and made with drill holes only or wire wound to any mesh desired. At the top of the screen is a left-hand nipple 2 or 3 ft. long with the left-hand thread up. By putting the proper tension on the drill pipe and turning, the left-hand thread unscrews and leaves the screen in the hole. The wash pipe is pulled out by the pulling ring.

When the coupling (6 or 8 in.) containing the pulling ring is landed on the elevators at the surface and the joint above unscrewed then the wash-pipe elevators (2 or 2½ in.) may be put on under the top coupling of the string and the wash pipe pulled.

Plugging Top of Screen for Cementing

A soft wooden plug about 20 in. long is made as shown in Fig. 9. The bottom of the plug is made conical as a guide in entering and the body cylindrical to fit tight into the screen nipple, which has a left-hand thread.

The top is rounded over to guide the swedge nipple that is later placed to fit down over the left-hand thread. A 1½-in. vent hole is bored through the axis of the plug in order to allow mud to flow back into the drill pipe in setting the plug.

A countersink 6 in. deep is made in the top of the plug so that it may be fitted on the end of the (4-in.) drill pipe. A piece of leather is nailed over the vent hole in the bottom of the countersink so as to make a flap valve.

The plug is then run in on a string of drill pipe to bottom.

I have found by experience that enough loose material will be pushed ahead of the plug to pack efficiently outside the left-hand nipple so that no cement will flow down outside the screen in cementing. Pump pressure is put on the drill pipe, which closes the flap valve in top of the plug. The string is raised and the drill pipe pulls out of the plug, an immediate fall of pressure being shown by the pump gauge, indicating that the plug is left in place.

The string of pipe is pulled out and the well is then in shape for running in a string of casing and cementing.

Cementing in the Casing Above the Screen

On this string should be a by-pass nipple, as previously described. Whether a back-pressure valve is to be used or not is determined by the

depth and condition of the well. The string (if 8-in.) should have on its bottom end a 9 by 8 in. swaged nipple. The 9-in. end should be cut with an offset and the lip thus formed bellied out slightly as indicated in Fig. 10. The purpose of this lip is to guide the plug and screen in line by turning the casing and to give a "feeling" which will indicate whether the swedge nipple is resting on top of the plug or has slipped down over the left-hand thread as it should. The string is lowered to bottom and marked, then pulled up until the circulation of mud is good.

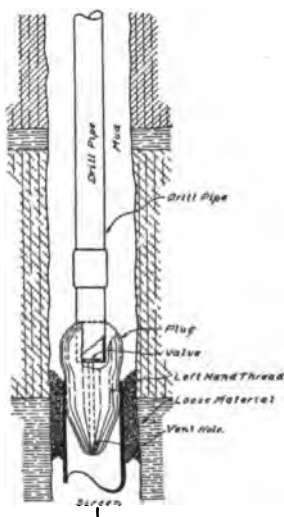


FIG. 9.

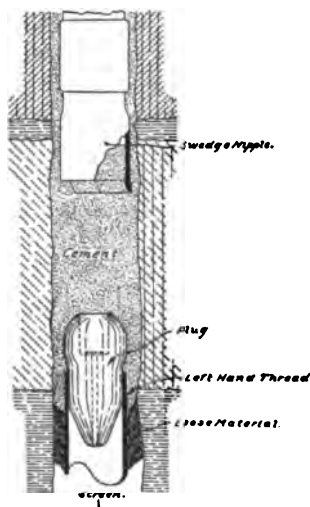


FIG. 10.

The cementing operation may be done by the methods already described. After the cement has had time to harden, five days should be plenty, the wooden plugs, brass bars, and back-pressure valve may be drilled out, the inside of the screen washed out with mud down to the wash-pipe plug and the drill pipe then withdrawn. A gate valve should be put on the casing and the well is then ready to bail to test for oil or gas.

Plugging Wells by Cementing

The two-plug cementing system is well adapted to put in a cement plug in the bottom of a well to exclude water or fill a well any distance with cement mortar. For instance, if it is desired to plug off the bottom 20 ft. of a hole the proceeding would be practically the same as cementing in a casing but no by-pass nipple or back-pressure valve would be used and the drill pipe would be employed to pass the cement to the bottom of the hole. The bottom plug should be made 36 in. long, but not tapered, and bored full of holes, which are filled with lead so that the

plug will stay on the bottom. The operation should be so performed that the bottom plug will shut off the pump when it reaches bottom and not by-pass the cement as before described. The drill pipe should then be pulled back until the bottom plug passes out. About half the cement to be placed should be pumped through, then the drilling pipe should be pulled back proportionately.

The top plug and the sack should be used to push the cement ahead and to prevent mixture with the mud following.

In cementing off 20 ft. a surplus of cement mixture should be put in and the drill pipe pulled back only about 22 ft. from bottom and the mud circulation kept on for half an hour to dissipate the surplus cement.

By this method of building up a cement plug from the bottom there need be no time limit to the completion of the cement-plugging operation, as the drill pipe can be pulled back from time to time and cement kept going in until the hole is completely filled. The drill pipe should have a scavenger plug passed through it about every hour to keep it clear of set cement; the joints as disconnected at the top should be washed clear.

Short plugs should be made of neat cement. Larger ones may be cement-and-sand mixtures.

Difficulty of Getting Reliable Information

For instance, the catalogue of hydraulic rotary well-drilling machinery of a prominent oil-well supply company has an article on "Cementing Casing in Wells." I quote from it as follows: "Seventh: Force the plug into the well by running in the drill pipe on top of same until the plugs and cement reach the bottom of the hole; water should be run into the hole as the drill pipe is lowered."

This might be practical for shallow strings of casing up to 800 ft. But how about 2,000 ft.? If the drill pipe is stacked in trebles in the derrick it takes quick work to run in 1,000 ft. per hour, so, if it took an hour to mix the cement and get it in the top of the hole and two hours to run the plugs it would take close to three hours to get the cement to the bottom of 2,000 ft. of casing, when it would probably have set some—enough to be too hard to allow of its being forced up outside the casing into place. But why use a drill pipe for such purpose when the cement can be pumped down 2,000 ft. by the mud-pump pressure in 10 min. or less?

Quoting the same catalogue further: "Ninth: When in doubt of the plugs being together, a measuring line should be used for verification."

As a practical matter the length of the drill pipe is known by actual measurements so that the exact location of the plugs should be known when a drill pipe is run in as directed under the seventh item, so what verification is necessary with a measuring line?

Quoting further: "Eleventh: Cement will not set in oil. . . ."

Dry cement will not set if mixed with oil because there is no water to hydrate it. Cement properly mixed with water and poured into oil will set and harden in the oil, as I know by actual trial. It would be presumed that the well-supply houses would give clear and exact information in special articles in their catalogues relating to well work; but they are manufacturers and dealers and not experts on well operations. They are experts only on sizing up one's ability to pay for the goods ordered.

Water Supply Paper No. 257, U. S. Geological Survey, on Well-Drilling Methods, in describing the hydraulic rotary method under "Drilling Operations," p. 71, says: "Drilling is accomplished by rotating the entire string of casing, on whose lower end is a toothed cutting shoe."

It would be practically impossible to drill a well 1,000 ft. in depth with a toothed cutting shoe on a string of casing in any possible formation. A casing that is to be set either as a water-excluding string or as an oil or gas string is never used to drill with. It is true very pretty pictures have for years past appeared in various well-supply dealers' catalogues showing how wells are drilled with rotary shoes, but as a practical matter wells are never drilled in this way. A rotary shoe is a very useful tool to run in with a joint of casing on a drill pipe to take lumps out of a hole and straighten it preparatory to casing. A rotary toothed cutter is sometimes used in core drilling, but the kind of rock or other material it will work in and produce a core from is very limited.

From "Special Operations," p. 74, I quote: "In penetrating firm material it is sometimes necessary to employ a rotary drill bit instead of a rotary shoe. Two styles of bit for this purpose are in general use—the diamond-shaped and the fishtail. The diamond-shaped is usually first employed, and the fishtail afterward used for reaming or enlarging the hole."

Now, this is all wrong. I will venture to say that 99 per cent. of all rotary drilling is done with a fishtail bit. The Sharp & Hughes bit is used for rotating on hard rock.

But why drill a hole too small and then ream it down? What is gained? As a matter of fact it usually takes longer to ream 100 ft. of hole than it would to drill the same 100 ft. of the full-sized hole at the first operation. Skillful rotary drilling completes the hole to the full size required and "muds up" all at one operation.

Technical Paper No. 32, Bureau of Mines, on Cementing Process of Excluding Water from Oil Wells as Practiced in California, gives under "Recommendations and Suggestions," p. 7, the following: "3. The well should be cleared of all débris and mud and enough clear water should be pumped in to wash out any sulphur or alkaline water."

To pump clear water into any well at any time before its completion is a questionable proceeding, even if drilled with the cable tools in a

hard formation. In wells drilled in unconsolidated formations with the rotary such action would mean complete destruction of the well. Only after all cementing is done and the well is completed and fully protected by casing or screens is washing with clear water practicable.

Quoting again from the same source: "5. Previous to cementing, some definite information should be gained relative to the action of the water in the hole on the setting qualities of the cement."

I regard it as not to the point to talk about the action of salt, alkaline, sulphur, or gypseous water or oil in the hole on cement when the neat Portland cement is first hydrated with suitable water, mixed on the surface, and passed with practically no chance of serious contamination to its final place.

Quoting again from the same: "An excess of gypsum in the water might delay the setting of ordinary cement three or four months."

I would be glad to be "shown" on a statement of this kind. Experiments of E. Candlot, an eminent cement expert (*Sibley Journal of Engineering*, January, 1905), show that when gypsum was ground with cement clinker in the ratio of $1\frac{1}{2}$ parts in 100, which proportion was found to produce the best effect in retarding the set, the maximum time for initial set was 5 hr., and final set 19 hr., and not three or four months.

Technical Paper No. 43, Bureau of Mines, on p. 6, describing a blow-out preventer, says: "The preventer, when used, is always placed on the last string of casing set or landed, thus controlling the flow between that string and the drill pipe or casing that is being lowered." Then, same page, under "Sealing of Artesian Water or Gas Strata" says, "This end can be easily accomplished in drilling with a rotary rig by forcing muddy water to the bottom of the well through one of the lateral openings of the preventer."

Suppose, for instance, the preventer casing was set at 700 ft. and the drill was working at 1,000 ft., leaving 300 ft. of hole open. It would be a practical impossibility to mud the bottom of the hole by pumping muddy water into the top of the well between the casing and drill pipe.

It is an elementary requirement in rotary drilling and mudding to have a mud circulation down the drill pipe, or a casing, and up between this pipe or casing and the walls of the well, if any mudding is to be accomplished.

The wobble of the rotary-drill stem must do the plastering; it cannot be efficiently done in any other way. Under the same head comes a most surprising statement: "The mud can easily be removed by releasing the pressure or bailing down the water in the hole."

But it is not necessary to quote more. The educated engineer that desires some information on well drilling and operating cannot possibly study out how mudding and cementing is really done from such a report. In marked contrast one can find in the Institute *Transactions* exact,

clear, and authoritative information on drilling holes in prospecting for coal, also on mining and preparation of coal for market, furnished by men who have actually performed the work. Unfortunately, petroleum mining has not had like information on drilling wells, and on refining and marketing the oil.

There were over 25,000 wells drilled for oil and gas in the United States east of the Rocky mountains the past year, or a well completed every 21 min. Their average cost was probably between \$2,500 and \$3,000 each, or between \$50,000,000 and \$75,000,000 was expended in drilling to keep up the supply of oil and gas.

It is really surprising that no more has been written upon the art of drilling wells and producing oil and gas by men experienced in these matters.

The recent formation of a technical committee on Petroleum and Gas by the American Institute of Mining Engineers comes at an opportune time, and I trust that this action will bring out in the future as valuable and accurate information on petroleum mining as the Institute has in the past published on coal mining.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at a meeting of the Institute. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y. Unless special arrangement is made, the discussion of this paper will close Apr. 1, 1914.

The Killing of the Burning Gas Well in the Caddo Oil Field, Louisiana

BY C. D. KEEN, SHREVEPORT, LA.

(New York Meeting, February, 1914)

In the latter part of the summer of 1913 the Conservation Commission of the State of Louisiana, under presidency of M. L. Alexander, decided to stop the waste of natural gas going on at the "burning gas-well," located about $\frac{1}{4}$ mile southeast of Oil City, La. On several occasions, both in newspapers and in reports, comment had been made on the condition of this well, its harmful effect on the Caddo gas field, and the considerable loss, estimated at several thousand dollars each month, caused by the escape of the valuable fuel. But nothing had been done to bring the well under control and prevent further waste of gas until the State Conservation Commission took the matter in hand.

The gas fields of Louisiana are among the greatest in the country. So far most of the gas has been found in the Caddo field proper, although considerable development has been done in and around the city of Shreveport and near the town of Mansfield in DeSoto parish. To extend the life of the gas fields and to prevent the quick exhaustion of the supply of the natural fuel are matters of vital importance for this section of the country.

Four gas companies have entered the Caddo field and supply the surrounding towns and cities with gas. The Arkansas Natural Gas Co. has pipe lines to Little Rock, Ark., and supplies gas to the following cities and towns in that State: Texarkana, Hope, Garland, Emmet, Prescott, Boughton, Beirne, Gurdon, Arkadelphia, Gum Springs, Malvern, Donaldson, Gifford, Perla, Beaton, Beauxite, Mabelvale, Bryant, Sheridan, Pine Bluff, Little Rock, Argenta, Pulaski Heights, and Hot Springs. The Southwestern Gas & Electric Co. transports gas to Mooringsport, Blanchard, Caddo, Rodessa, Oil City, Vivian, Bloomburg, Hosston, Ida, Dixie, Belcher, and Shreveport. The Marshall Gas Co. supplies gas to the town of Marshall, Texas. The Louisiana Co. has a line to Shreveport.

In the oil field the gas is used for drilling purposes, and the operators either have their own gas system or buy from the gas companies. At the present time the surrounding territory depends for its fuel supply on the Caddo field, and the importance of the conservation of the natural-gas

resources of the State was fully appreciated by the Commission, when it ordered the killing of the "wild well."

The object of the present paper is to give an account of the effective method by which the Commission, represented by its Agent, J. W. Smith, brought the well under control, by drilling a relief well to the

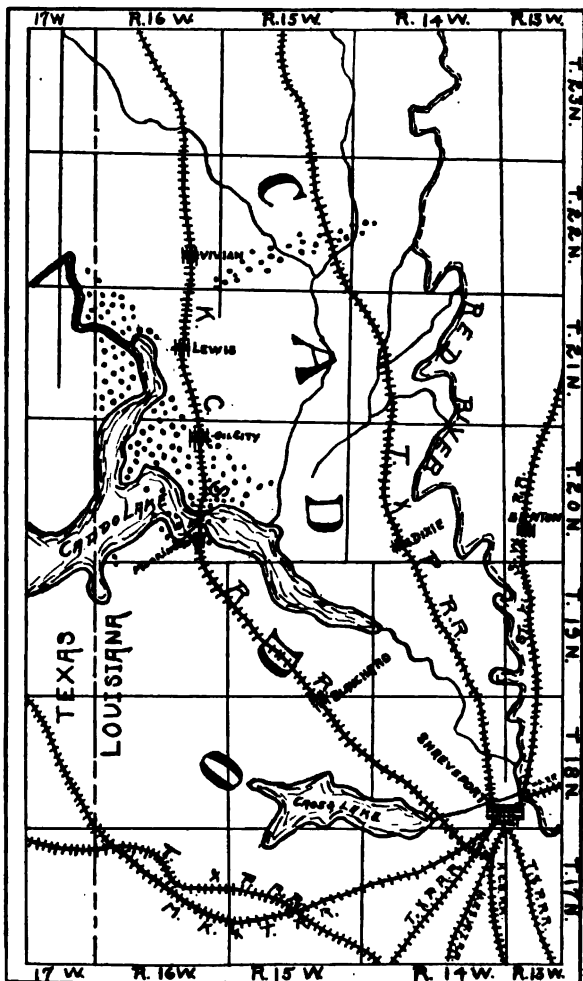


FIG. 1.—SKETCH MAP OF THE CADDO OIL FIELD, CADDO PARISH, LA.

stratum from which the well was blowing out and forcing water under high pressure through the bore hole into the gas sand.

It may be useful to give a short sketch of the geological occurrence of oil and gas in the Caddo field. Those interested in the subject are referred to *Bulletin No. 429, U. S. Geological Survey* (Oil and Gas in Louisiana, by G. D. Harris), for a complete description of the field.

Location

The oil and gas field is located in Caddo parish, in the northwestern part of the State of Louisiana, about 20 miles north of the city of Shreveport, as shown in Fig. 1. The field proper begins at the town of Mooringsport and extends in a direction west of north for about 12 miles, the width of the field ranging from 6 to 8 miles.

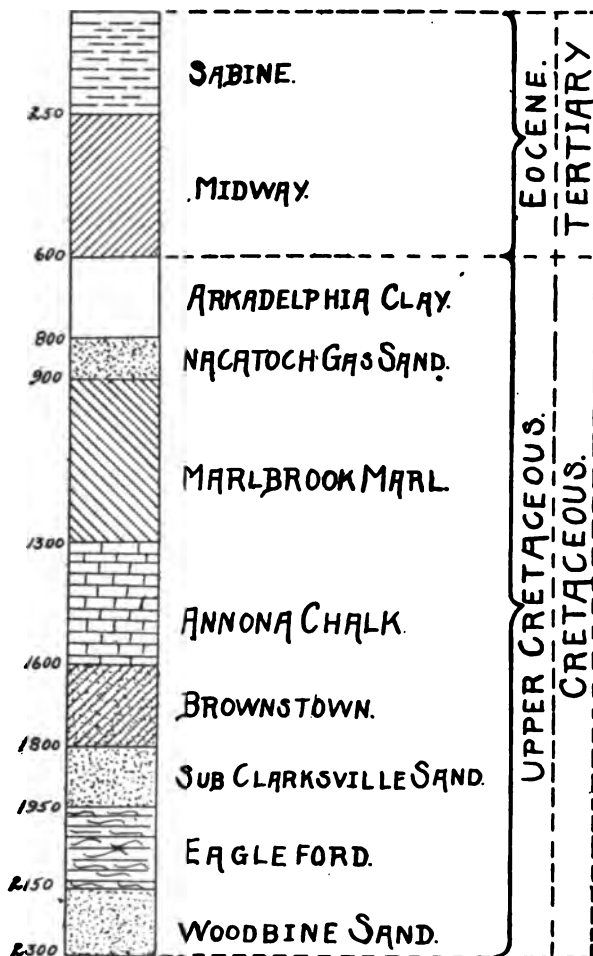


FIG. 2.—LOG AND SECTION OF A CADDO WELL.

Occurrence of Oil and Gas in the Caddo Field

The strata encountered by the drill in the Caddo field belong to the Lower Tertiary and Upper Cretaceous. They consist mostly of soft shales, marls, and clays, with the exception of the Nacatoch sand, the

Annona chalk, the Sub-Clarksville sand, and the Woodbine sand. Fig. 2 is a general section of the strata.

Nacatoch Sand.—The Nacatoch sand is encountered at a depth ranging from 750 to 850 ft. from the surface, according to local topography and stratigraphy. The upper part of the formation is developed as a close, hard quartzite, the thickness of which varies from 8 to 10 ft. The quartzite is an excellent cap rock for the gas, found in the sand below. The gas formation is a close, fine-grained sandstone or a packed sand, the thickness of which seldom exceeds 20 ft.

Directly under the gas sand, still in the Nacatoch formation, the drill strikes sand beds which contain salt water. Great precaution has to be exercised not to drill a gas well into salt water and it is not advisable to enter more than 8 or 10 ft. in the gas formation. The total thickness of the formation may be estimated at 100 ft.

In that part of the field known as the Shallow Territory, lying east of the town of Vivian (see Fig. 1), the Nacatoch sand yields a heavy fuel oil.

When the Caddo oil field was first discovered the gas from the Nacatoch sand gave the drillers considerable trouble on account of the high rock pressure, which at the time was 450 lb. to the inch. On several occasions the drilling mud was blown out by the gas and the wells could only be kept under control with great difficulty. The rock pressure quickly declined, however, partly because of the enormous quantities of gas used for commercial purposes, partly on account of a great volume of the fuel going to waste. At the present time the rock pressure of the Nacatoch gas sand does not exceed 100 lb. to the inch.

Sub-Clarksville Sand.—The Sub-Clarksville sand is the second gas horizon in the field. It is encountered at a depth ranging from 1,800 to 1,900 ft. Its structure is almost identical with that of the Nacatoch sand. It has shown gas under high pressure in several wells, but so far the Nacatoch sand furnishes practically all the gas now being used from the Caddo field. Like the Nacatoch sand, the bottom of the formation contains salt water in great quantities. Its total thickness varies from 75 to 150 ft.

Woodbine Sand.—This is the horizon from which the bulk of the oil in the Caddo field is obtained. It is overlain by the Eagleford shales. There are no sharp lines of division between the two formations. At a depth of about 2,150 to 2,200 ft. the Eagleford shales become more sandy and change gradually into the Woodbine. The Woodbine is developed in Caddo as a series of interstratified sands and shales; the horizontal as well as the vertical distribution of the sand in the shale is very irregular, caused by the thinning out of the sand lenses and the grading into sandy shale and shale. It is a typical shallow-water deposit, the sudden changes in structure being caused by changing tides, winds, and

currents. It is in these sands that the big oil wells, for which the Caddo field is famous, are struck. In the bottom of the Woodbine, under the oil-bearing sands, salt water is encountered, as in the gas sands.

Annona Chalk.—Mention must be made of the occurrence of oil in places in the Annona chalk. The "chalk rock" is struck at about 1,300 ft. and has a thickness of 300 to 350 ft. The occurrence of this oil is not sufficiently explained. From the data at hand it seems that the oil fills crevices which have been caused by slight faulting.

History of the "Burning Well"

The well is situated in the SE. $\frac{1}{4}$ of the NE. $\frac{1}{4}$ of the SW. $\frac{1}{4}$ of Section 7, T. 20 N., R. 15 W., on a 10-acre tract owned by B. G. Dawes,

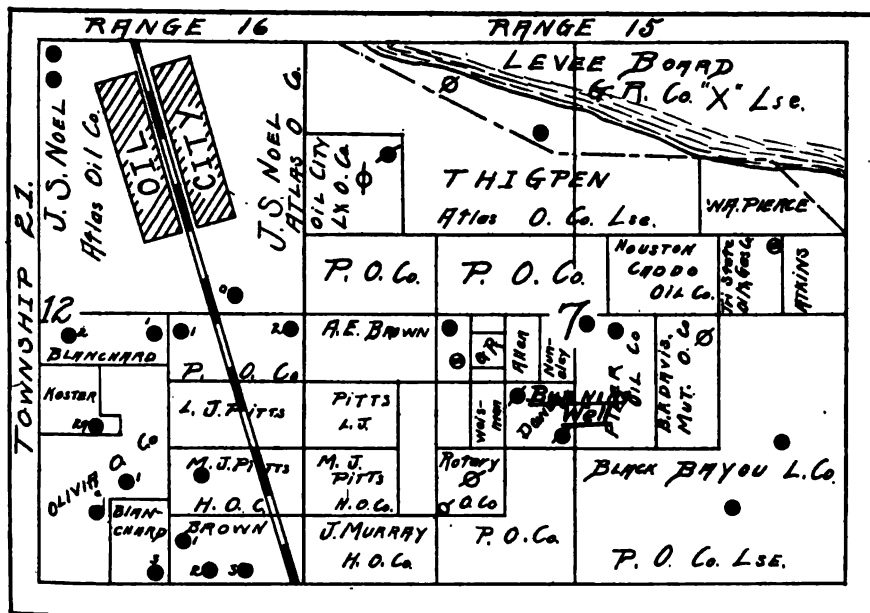


FIG. 3.—MAP SHOWING THE LOCATION OF THE BURNING WELL.

Trustee. Fig. 3 is a map of the region. Work on the well was started on Mar. 17, 1908. On May 11, 1908, the drillers had reached a depth of 2,065 ft. The well was cased off with 300 ft. of 10-in. casing pipe and 900 ft. of 8½-in. casing pipe. The 6-in. casing pipe was not set yet. During the day the well began to give trouble and blew out from the 1,800-ft. gas stratum (Sub-Clarksville sand). The drilling mud was made as heavy as possible and the driller started to pull the 4-in. drill pipe out of the hole to change the drill bit. In the night during a heavy rainstorm, while the 4-in. drill pipe was being put back and was

about 350 ft. from the bottom, the well blew the drilling mud out again with much more violence than before. The gas pressure raised the drill pipe up, which unlatched the elevators and the drill pipe dropped 350 ft. in the bore hole.

The well continued to blow out, increasing all the time in volume, which was estimated the next day at 40,000,000 cu. ft. in 24 hr. The well also made a strong salt-water flow. The owners of the well did everything in their power to get the well under control. A lubricator¹ was made of two pieces of 8½-in. pipe and screwed on the 8½-in. casing to kill the well, but as soon as the valves were closed the gas broke the seats of the 8½-in. and 10-in. casings and began to blow out under the derrick floor. The valves on the lubricator had to be opened up again, to release the pressure from the casing, but the flow of gas around the 8½-in. casing had relieved the pressure of the drilling mud on the 800-ft. gas, which now started to blow out between the 10-in. and the 8½-in. casings.

On the evening of May 13 a cyclone completely destroyed the derrick and drilling rig. A deep hole was dug around the 10-in. casing, with the well open, flowing gas and salt water, with the object of putting a cement block around it, which might hold the gas back long enough to lubricate the well. At 20 ft. from the top a split was found in the 10-in. casing pipe. After several days the drillers succeeded in getting a joint of 14-in. pipe over the 10-in. pipe and the two were cemented together, and a big block of solid cement was placed around the casing. The cement was allowed several days to harden, while the well was blowing gas and salt water. Then a second attempt was made to lubricate, but the pressure was so strong that the gas escaped outside the 10-in. casing into the shallow-water sand, which is found at about 75 ft. in that part of the field, and blew out on the ground about 300 ft. away from the well. The well had to be opened up again and all the material brought in safely and a last attempt made to kill the blowout. But the gas continued to escape around the well, coming closer and closer to the hole. The owners

¹ A well is killed with a lubricator in the following manner: Two lengths of pipe, with gate valves at the top and bottom, are screwed on the casing of the well, the lower valve is closed and the two pieces of pipe filled with heavy mud. Then the upper valve is closed and the lower valve opened. The pressure in the well and in the lubricator becomes equal and the mud drops through the lower valve into the well. The lower valve is closed and the upper valve opened again and the operation is repeated until the bore hole is filled to the top with heavy mud and the blowout stopped. The operation of lubricating takes considerable time, and nowadays a better method is used. The well is directly connected up with a line pump, that can put up a pressure of 700 or 800 lb. to the inch. Then the well is closed in and the pressure in the well runs up to the rock pressure; but the pump is able to work against that pressure, and the bore hole is filled with mud in a much shorter time than with the lubricator.

then abandoned the well, considering it impossible to get it under control. In less than three weeks' time the escaping gas and water had formed a crater around the well at least 100 ft. in diameter, which the waves made larger and deeper as the time passed.

In June, 1908, the well was put on fire because the gas was a continuous danger to those who had to work and live in the surrounding woods. The well stopped burning in February, 1909, but caught fire again soon afterward. The well was allowed to run wild until the summer of 1913. Most of the time the gas was burning, but heavy rainstorms and wind would put it out. After a few days the gas would catch fire again. The muddy waves caused by the escaping gas kept on washing more and more material in the hole, thus increasing the size and depth of the crater, until finally they had formed a circular pool 225 ft. in diameter, in the center of which the escaping gas threw up a body of mud 25 or 30 ft. high.

The volume of the gas escaping from the well at the end of its life was estimated by experts to be between 8,000,000 and 10,000,000 ft. per day. Not only was this waste of gas deplorable, the value of which, at about $2\frac{1}{2}$ c. per 1,000 cu. ft. at the well, amounted to about \$250 per day, but also the well affected the rock pressure of the surrounding territory, which had fallen below 100 lb. to the inch, and allowed the salt water which occurs in the bottom of the Nacatoch sand to enter the gas formation.

Killing of the Well

When the Conservation Commission took the matter in hand it was decided to first empty the pool which the blowout had made, to find out the condition of the casings. It took about 20 days to empty the crater. The shape of the crater is shown in Fig. 4. The bottom of the pool sloped from the border for about 50 ft. until it reached a depth of about 10 ft. below the surface. From there the crater had a conical shape, with a diameter of about 125 ft. sloping down to the old bore hole, where it had a depth of from 37 to 40 ft. The top of the 10-in. and the $8\frac{1}{4}$ -in. casings could be seen in the bottom of the crater. The well was not blowing outside the 10-in. casing pipe. Evidently after the pressure of the well had gone down, the caving mud had fallen in around the 10-in. casing so that the water and gas could only escape between the 10-in. and $8\frac{1}{4}$ -in. casings. It was observed that the well blew out cold salt water, which showed from what depth the blowout was taking place, because the salt water found in the deep sand rock is warm, whereas the water from the Nacatoch sand has a much lower temperature.

The tops of both casings were worn very thin and it was impossible to screw any connections on to them. The original plan was to set a

disk wall packer inside the 8½-in. casing on 4-in. pipe about 100 ft. from the top and let the well blow through the 4-in. pipe, then pack the space between the 8½-in. and the 10-in. casings with a stuffing-box casing head and make a cement block outside the 10-in. casing, after which the well perhaps could be closed in. But the condition of the top of the casings would not allow this scheme to be carried out. Then it was de-



FIG. 4.—VIEW OF CRATER OF BURNING WELL AFTER BEING PUMPED DRY.

cided to drill a well, which was called a "relief well," as close to the old hole as was possible under the circumstances, and to try to stop the flow of gas and water by pumping water or mud in the gas formation. The contract for drilling the well was let to W. W. Blocker.

When the pumps were moved the crater filled up with the salt water thrown out by the well.

This relief well was drilled on the southeastern side of the crater, at a distance of 125 ft. from the center, as shown in Fig. 5. The hole was

cased off with 211 ft. of 10-in. casing and 792 ft. 11 in. of 8-in. casing pipe, both cemented. The 8-in. casing pipe was set on the top of the Nacatoch sand. The cement was allowed to harden for nine days, after which the seat of the 8-in. casing was tested. Mr. Smith ordered

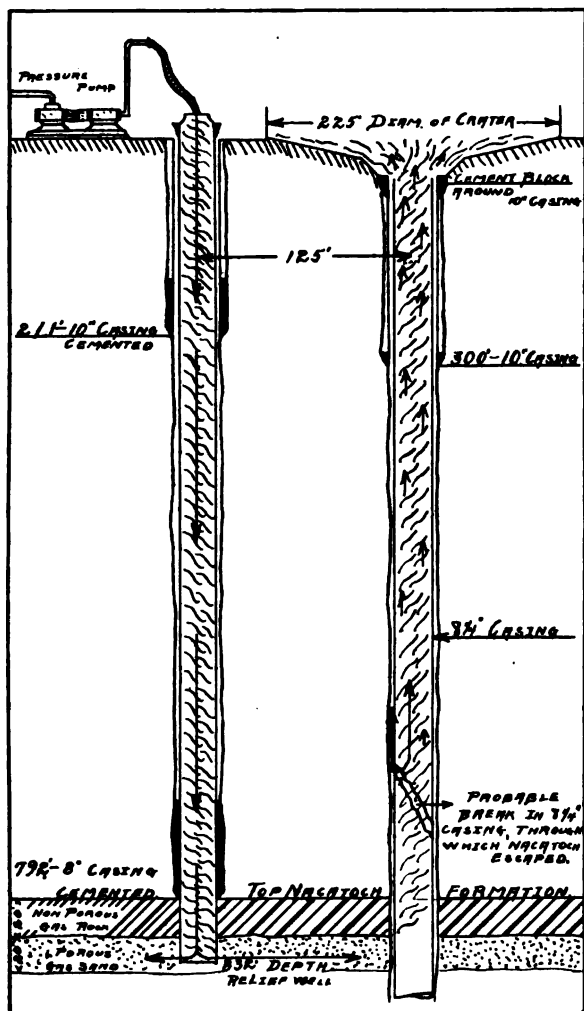


FIG. 5.—SECTION THROUGH BURNING WELL AND RELIEF WELL.

the well to be drilled with clear water 20 ft. in the Nacatoch formation. The rock encountered in this 20 ft. was not porous enough, in the judgment of Mr. Smith, to attempt to pump in water. The well was then drilled 20 ft. deeper in the same formation, the total depth being 832 ft.

The formation found in the last 20 ft. was a coarse sand rock, considerably more porous than the first 20 ft. below the 8-in. casing. It was

decided to make the experiment at this depth. A reservoir covering 3 acres of land, ranging in depth from 6 in. to 3 ft., was filled with water, and the 8-in. casing was connected with the pump and the full pressure put on the formation.

The pump used was an ordinary 10 by 6 by 12 in. rotary drilling pump; the boiler pressure was 120 lb. per inch and the pressure put up by the pump as registered by the gauge was 310 lb. per inch. After the hole was filled, the pump ran at about 5 rev. per minute for 1 hr., corresponding to a volume of about 29 gal. per minute being forced into the gas formation. During the next 5 hr. the number of revolutions increased slowly from 5 to 10 per minute, but the gauge registered the same pressure. During the following days the full pump pressure was left continually on the well, the number of revolutions increasing gradually and the pressure against which the pump had to work decreasing. After the fifth day the pressure registered on the gauge was about 150 lb. to the inch and the number of revolutions 30 per minute, which was equivalent to a volume of 165 gal. being forced into the gas sand each minute.

On the seventh day the pressure was 50 lb. to the inch and the pump was running at the rate of 42 rev. per minute. It was noticed that the pressure would fall considerably for a short time and then run up again to where it had been previously, which can only be explained on the hypothesis that the water opened up a new channel in the formation, thus relieving the pressure, and when the cavity was filled the pressure went up again to the point where it had been before. From the seventh day on a slow decrease in the strength of the eruptions was noticeable, and on the tenth day the eruptions ceased. At the moment the eruptions stopped the salt water and mud in the pool flowed back in the old bore hole, leaving the crater entirely empty.

Although there was no gas escaping from the hole, the pumping was continued for three more days, to drive the gas still further back in the formation and away from the well.

The space between the 8½-in. and the 10-in. casings was filled with cement and a heavy cement block was put around the 10-in. casing. Then several blasts of dynamite were fired around the circumference of the crater about 10 ft. apart. The explosion caused several tons of shale and clay to fall to the bottom of the crater. If the well should start to flow gas and salt water again, the salt water would mix with this shale and clay and make a thick mud, which would kill the well.

Although the blowout was killed successfully, and the possibility that the well will give trouble again is very small, the derrick and casing were not removed from the "relief well," as a further precaution, so that work can be started at a moment's notice to pump water in the gas sand and cut off the flow of gas.

Value of Gas Wasted and Conserved

A low estimate of the average production of the well during the five years that it ran wild puts it at 15,000,000 cu. ft. per day. The volume of natural gas which escaped into the atmosphere during this time would be 27,000,000,000 cu. ft. At $2\frac{1}{2}$ c. per 1,000 cu. ft., this volume of gas represents a value of \$675,000.

In the town of Shreveport the selling rate for manufacturing gas is 7 $\frac{1}{16}$ c. per 1,000 cu. ft. If all the gas which went to waste at the burning gas well had been sold in the city of Shreveport for manufacturing purposes only, it would have brought in \$2,079,000.

At the time the well was killed the eruptions were still very violent and during the last year no decrease in their strength had been noticeable. No doubt it would have been several years before the burning well would have died a natural death. It is impossible to estimate the value of the gas that has been saved by the energy and activity of the Conservation Commission, but from the above figures it can be seen that it must amount to several hundred thousand dollars.

The cost of drilling the "relief well" and putting out the burning well was approximately \$6,000, which is a very small amount compared with the value of the gas saved.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at a meeting of the Institute. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street New York, N. Y. Unless special arrangement is made, the discussion of this paper will close Apr. 1, 1914.

The Age and Manner of Formation of Petroleum Deposits

BY E. T. DUMBLE, HOUSTON, TEXAS

(New York Meeting, February, 1914)

PROF. EDWARD ORTON, in his *Report on the Occurrence of Petroleum, Natural Gas and Asphalt Rock in Western Kentucky*, thus clearly states his ideas of the universal dissemination and rare accumulations of the bitumens:¹

"We need to bear in mind that the various members of the bituminous series are abundantly and almost universally distributed among the unaltered sedimentary rocks of the earth's crust. The valuable accumulations of these substances are rare, it is true, but one can scarcely go amiss of petroleum, asphalt or gas, at least in small quantities, among the stratified rocks that retain their original structure."

Speaking of the Ohio valley, he adds:

"A fifth of one per cent. of petroleum, if distributed through a thousand feet of rock, would make a total to the acre, or square mile far beyond any production that has ever been realized from the richest oil field, and percentages of this amount are not only not rare to find, but are even hard to miss."

Dr. F. W. Clarke in his *Data of Geochemistry* (*Bulletin No. 491, U. S. Geological Survey*, 1911), discussing these views of Orton with similar views of T. Sterry Hunt and Szajnoch, says that they "lead to the conviction that the formation of bitumens is a general process and by no means exceptional. Wherever sediments are laid down, inclosing either animal or vegetable matter, there bitumens may be produced."²

The organic origin of the bitumens, including petroleum, has long been an accepted fact with nearly all geologists, but the method, place, and time of the transformation into petroleum or other bitumen is still under discussion.

Dr. Orton says:³

"The statements now presented. bring before us two main views as to the origin of petroleum, viz.:

"(1) Petroleum is produced by the primary decomposition of organic

¹P. 30. (Kentucky Geological Survey, 1891.)

²P. 703.

³P. 42.

matter, and mainly in the rocks that contained the organic matter. Of this view Hunt is one of the chief advocates.

"(2) Petroleum results from the distillation of organic hydrocarbons contained in the rocks, and has generally been transferred to strata higher than those in which it was formed. Newberry and Peckham have been quoted at length in support of this general theory. Newberry holds that a slow and constant distillation is in progress at low temperatures. Peckham refers the distillation of the petroleum of the great American fields to the heat connected with the elevation and metamorphism of the Appalachian mountain system."

Discussing the age of petroleum deposits, Dr. Orton says:⁴

"These three views, as to the date of the origin of petroleum and gas, are seen to cover almost all of the possibilities in regard to the subject. Hunt believes petroleum to have been produced at the time that the rocks that contain it were formed, once for all. Newberry believes it to have been in process of formation, slowly and constantly, since the strata were deposited. Peckham refers it to a definite but distant time in the past, but long subsequent to the formation of the petroliferous strata. He supposes it to have been stored in its subterranean reservoirs from that time to the present."

To the distillation theories of Newberry and Peckham, Orton raises the objection that they do not harmonize with the facts of geology in the main oil fields, and discusses these at some length. He, however, accepts in his earlier writings the essential point in Hunt's theory of the origin of petroleum, "that it results from the primary decomposition of organic substances," but without subscribing to his views that it was produced contemporaneously with the rock, nor that it is especially a product of limestones. In his later writings, however, he seems to have held that this theory was not fully sustained by the facts, and says:

"What geologists would be glad to find in nature as matching to and harmonizing with the facts with which they are obliged to reckon would be a process in which the products of the organic world are transformed into mineral oil at ordinary temperatures and with complete consumption of the substances acted on, so that no carbon residue would be left behind. They would also expect the transformation to be accomplished while the organic matter still retained essentially its original character."

He is strong in his belief that petroleum is the primary product and that the other members of the bituminous series—namely, natural gas, maltha, or mineral tar, and asphalt—are derived from it. In his last printed report, he says of it:⁵

"Petroleum seems to be, when thus protected from the air, one of

⁴ P. 42.

⁵ Petroleum and Natural Gas in New York, *Bulletin No. 30, N. Y. State Museum* (1899).

the durable forms that organic matter can assume. There seems no reason to believe that it is less permanent than coal. Stored in the rocks in the morning of the world it can apparently remain in this condition through the vast and indefinite ages of geology."

In the decades that have passed since the publication of these views, the principal advance which has been made in the theories relative to the formation of petroleum is the development of the theory that the first step in such formation is the separation and segregation of the fatty materials from the remains of plants and animals by the action of bacteria. Upon this point there now appears to be substantial agreement among most geologists. As to the manner, time, and place of the transformation of these fatty materials into petroleum, however, they are, seemingly, as far apart as ever.

A review of the publications bearing on the subject indicates that by far the greatest number of writers, both American and European, still hold by the theory that the production of petroleum from the fatty matters is brought about by some form of pressure or temperature acting on the materials after they have been entombed in the rocks.

Engler says:

"The transformation of the fatty materials into petroleum has been accomplished under very diverse conditions of pressure, of temperature and in cycles of time of different duration."*

Dr. David White, speaking of the rapid disintegration of animal matter in sapropelic deposits, says:

"This forcibly suggests that the algæ, which almost certainly have exerted an attraction for certain bitumens of extraneous origin, may have played the important rôle, first of storing up some of the hydrocarbon products of the decaying animal matter; and later, under dynamic influences, of releasing a part, at least, of the stored, as well as, presumably, of their own original contents in the form of petrolic or gaseous hydrocarbons.

"There is little doubt in the mind of the writer that the oils and gases of the Mesozoic and Tertiary, as well as of the Paleozoic, are directly derived, in most cases at least, from dynamic distillation of algal débris, though in part originally of animal origin."

He thus attributes its production to a time subsequent to the deposition of the beds containing the algal débris.

Similarly, Dr. F. W. Clarke, without expressing his views as to the direct cause of the transformation, believes this transformation to take place after burial:

"Wherever sediments are laid down, inclosing either animal or vegetable matter, there bitumens may be produced. The presence of water,

* Int. Pet. Cong., Bucarest, vol. ii, p. 35 (1910).

preferably salt, the exclusion of air, and the existence of an impervious protecting stratum of clay seem to be essential conditions toward rendering the transformation possible."⁷

Cunningham-Craig also states his belief in the derivation of petroleum by pressure-distillation of organic matter (terrestrial vegetation) buried in the rocks:

"It seems probable—but here we enter into speculation—that it is the *pressure* that is the determining factor, as it is in so many chemical reactions. Given the vegetable matter from which petroleum can be formed enclosed in a well sealed deposit, given the presence of a limited quantity of water, and the necessary, but by no means high, temperature, as soon as the pressure reaches a certain point the action will begin."⁸

While it is not denied that petroleum can be, and has been, produced by a process of distillation from organic matters entombed within the rocks beneath the surface of the earth, the arguments adduced by Orton against the probability of such pressure distillation having taken a prominent part in the production of the principal accumulations of petroleum from entombed organic debris are just as valid against the claims of more recent writers who invoke its aid in the transformation of the buried fatty matter derived from such organic materials.

Orton's arguments have been repeated and added to by Dalton, Clarke, and others, and seem to me to be in full accord with facts of observation. Professor Hoefer also comes out positively against this theory of pressure distillation and substitutes for it a process of fermentation.

One of the early statements by Dr. Hunt regarding oil in the limestones is as follows:⁹

"The facts observed in this locality appear to show that the petroleum, or the substance which has given rise to it, was deposited in the beds in which it is now found at the formation of the rock. We may suppose in these oil-bearing beds an accumulation of organic matters whose decomposition in the midst of a marine calcareous deposit has resulted in their complete transformation into petroleum."

He thus indicates the probability that the formation of petroleum is, or may be, contemporaneous with the deposition of the rock material.

This has been more clearly stated by Murray Stuart:

"The oil represents a contemporaneous flow and was deposited in practically its present state,"¹⁰ and in his adaptation of the existing theory of the derivation of oil from the fatty materials of plants and animals in the sediment itself to suit the altered view that oil is of sedimentary origin in the deposits and is not a secondary product in them, he says:

⁷ *Data of Geochemistry*, p. 703 (1911).

⁸ *Oil Finding*, p. 28.

⁹ Tenth Census, p. 62.

¹⁰ Geological Survey of Indiana, vol. xl, p. 320.

"For this purpose it is necessary that the decomposition of the organic bodies should have proceeded elsewhere than in the strata themselves and yet in such a place that the oil would be retained and collected until it was liberated upon the surface of rivers which were depositing the sediment."¹¹

Munn, on the contrary, while also holding to the contemporaneous formation of petroleum with the sediments in which it is found, holds that it is generated in the loose mud and sand on the sea bottom, coming off very probably in microscopical globules and "because of the great affinity of oil for clay, each of these tiny globules immediately after being formed eagerly seized upon the first small particle of clay with which it came in contact and completely enveloped all exposed portions of it"¹²

It will be noted that both Stuart and Munn are discussing only the origin of petroleum found in the shales or the sandstones connected with them into which it may have migrated. The method of deposition outlined by Munn is based on the supposed affinity between the clay particles and oil globules, while Stuart maintains that "The deposition of oil is purely a matter of gravitation. The oil becomes mechanically mixed with the sediment and the fineness of that sediment renders it impossible for the oil to separate itself; the mixture of sediment and oil, being still of higher specific gravity than water, falls to the bottom and is deposited as a sedimentary deposit."¹³

We have here in contradistinction to the prevalent theory that the transformation of the fatty materials derived from organic remains into petroleum takes place after the burial of these materials in the sedimentary rocks, through the action on them of pressure distillation, or by some geo-chemic process, one which postulates the formation of petroleum from similar material, by natural processes, at the surface of the earth, without the interposition of geo-dynamic or geo-chemic agencies, and its contemporaneous deposition as petroleum with those sediments with which it is originally connected.

If this view, which has also been advanced by other writers than those named, can be maintained, even in part, it will, it seems to me, afford us an explanation of the origin of many petroleum deposits, the conditions surrounding which do not appear, in any wise, to fit the pressure-distillation theory.

The actual formation of petroleum and other bitumens at the surface of the earth in such relation to other sediments as might permit their deposition in the manner claimed for them seems to be fairly well established by observations in various parts of the world.

¹¹ Geological Survey of Indiana, vol. xi, p. 239.

¹² *Economic Geology*, vol. iv., No. 6, p. 519 (Sept., Oct., 1909).

¹³ Geological Survey of Indiana, p. 324.

"In 1866 Lesquereux referred to the recent formation of a liquid akin to petroleum in Sardinia and Sweden. In the former the salt-marshes are frequently covered with masses of sea-weed, and these can be observed decomposing into petroleum-like oil. In Sweden on the shores of the Sound in the neighborhood of Lund, sea-weed buried in the shore sand has been found to decompose into a similar substance."¹⁴

Newberry reports "that in the Bay of Marquette, where the shore consists of peat overlying Archean rocks, bubbles of marsh gas arise, together with drops which cover the surface of the water, in spots, with an oily film."¹⁵

Krmäer and Spilker call attention "to a possible derivation of petroleum from diatoms, which abound in certain bogs. These organisms, according to Krämer and Spilker, contain drops of oily matter, and from diatomaceous peat a waxy substance, resembling ozokerite, can be extracted."

"Krämer and Spilker's views have not met with very general acceptance, but they seem to contain elements of value. H. Potonié's hypotheses, for example, seem to be a broadening of Krämer and Spilker's. This writer calls attention to the 'faulschlamm' or 'sapropel,' a slime, rich in organic matter, which is formed from gelatinous algæ, and accumulates at the bottom of stagnant waters. Such a slime, Potonié believes, may be the parent substance from which bitumen, by a process of decay, was probably derived. In this connection, and with reference to the adequacy of the proposed source, it is well to remember the enormous accumulation of 'oozes,' namely, the raidolarian and globigerina oozes, on the bottom of the sea. The organic matter thus indicated is certainly abundant enough, if it can decay under proper conditions, to form more hydrocarbons than the known deposits of petroleum now contain."¹⁶

Dalton, discussing Krämer and Spilker's studies of the Gulf of Stettin, says:

"Opinions are divided as to whether ozokerite is a direct product of the decomposition of organic matter or of the natural desiccation and oxidation of liquid petroleum, but the researches at least point to the fact that natural decomposition of plant remains, especially of the lower forms, may give rise to petroleum-like substances."¹⁷

Observation of the direct formation of petroleum is given by Clarke as follows:

"E. Sickenberger has shown that in small bays of the Red Sea, where the salinity reaches 7.3 per cent., petroleum is actually forming as a

¹⁴ Dalton: *Economic Geology*, vol. iv, No. 7, p. 616 (Oct.-Nov., 1909).

¹⁵ Clarke: *Data of Geochemistry*, p. 701.

¹⁶ *Idem*.

¹⁷ *Economic Geology*, vol. iv, No. 7, p. 618 (Oct.-Nov., 1909).

scum upon the surface of the water. Living forms are abundant in these bays, and their remains, after death, furnish the hydrocarbons. The latter are to some extent absorbed into the pores of coral reefs, and so contribute to the formation of bituminous limestones. A still earlier publication by O. F. Fraas, contains data of similar purport. Fraas found in Egypt shells filled with bitumen, and noticed that the bituminous beds were rich in fossils, while the nonbituminous strata were poor. In the region of the Dead Sea, also, Fraas noticed that bitumen was abundant in beds of baculites, from which it exudes to accumulate upon the shore. In this connection it may well be noted that the brines which are so often associated with petroleum have, as a rule, a composition indicative of a marine origin, and do not resemble solfataric or volcanic waters. Furthermore, Mendeléef's objection to the possibility of forming petroleum at the bottom of the sea—namely, that being lighter than water it would float away and be dissipated—is not only negated by Sickenberger's observations, but also by the well-known fact that mud and clay are capable of retaining oily matters mechanically. The littoral sediments probably aid in the process of petroleum formation, if only to the extent of retaining the fatty substances from which the oil is to be produced. The beds of sulphur which occur adjacent to some oil wells, notably in Texas, were probably formed by the reducing action of organic matter upon sulphates, such as gypsum, a mineral which is often associated with marine deposits and with petroleum. The association of gas, oil, salt, sulphur, and gypsum, which some writers have taken as evidence of former volcanism, is much more simply interpreted, both chemically and geologically, as due to the decomposition of organic matter in shallow, highly saline waters near the margin of the sea."¹⁸

Dalton refers to other similar observations as follows:

"Natterer describes the occurrence of petroleum in the mud of the Mediterranean sea-floor between Cyprus and Syria, and in the sea-water immediately above the bottom; it was also found in the Gulf of Suez, and in each case ammonia and iron sulphide or sulphur occur with the oil. . . . But the present value of the 'Pola' observations lies in the fact that they show that at least in the Levant and the Red Sea so much organic matter is being buried in the sediments that the petroleum formed by its decay not only impregnates these rocks of the future, but is distributed through the lowest strata of the sea itself, sulphur or sulphides being also formed in the process."¹⁹

Dr. David White, while upholding the pressure-distillation theory for the production of petroleum, recognizes the fact of the formation of

¹⁸ Clarke: *Data of Geochemistry*, pp. 699, 700.

¹⁹ Dalton: *Economic Geology*, vol. iv, No. 7, p. 620 (Oct.-Nov., 1909).

other bitumens by organic processes in connection with the decomposition of fatty algæ mingled with animal matter in stagnant or quiet waters.

" the animal bacteria may have completed their work after the extinction of the plant bacteria beneath the surface of the rapidly increasing organic accumulation. The writer is disposed also to believe that the bituminous elements derived from the fully decomposed animal remains have participated to a very important extent in the infiltration of the thalli of the undestroyed algæ, thus enriching the latter with combustible matter of a distinctly bituminous character."²⁰

"An important point to be borne in mind is that the attractive selection of the bitumens and the consequent enrichment of the algal matter appears to have been accomplished during the first or biochemical change of coalification."²¹

The actual formation of petroleum and other bitumens in peat bogs, at the bottoms of bays, along the margin of the sea and even on the sea-floor, would, therefore, appear to be as well established as any of the facts upon which the pressure-distillation theory is based.

The association of such petroleum with sediments in course of formation, as already recorded, and the readiness with which surface petroleum is carried down and deposited by muddy waters are facts in favor of contemporaneous deposition, which is further sustained by many field observations which seemingly admit of no other explanation. This is especially true of the coastal fields of Texas and Louisiana.

The productive oil sands in this region are overlain by heavy blue clays, massive in structure and so dense as to be impermeable either to water or oil. They are known locally as "gumbo." These gumbos carry some included lenses of shale, but these are as a rule not individually extensive. They also carry small pockets of pulverulent gypsum and some iron pyrites.

In drilling wells throughout this region it is a common thing to find shows of oil, or pockets of oil, in the midst of these dense clays, as well as in the included shales. In a recent well drilled at Terry, in the eastern part of the State, we had several such shows of dark oil from the gumbos and one of nearly white oil from a small bed of shale hundreds of feet above the productive oil sand, and so separated from it by dense layers of gumbo that they could not possibly have been derived from it. The same conditions were observed in many wells drilled at Saratoga, Welsh, and in other coastal fields. So far as can be known there is no outside source for these oil shows, the clays have not been subjected to any special heat or pressure, or any decided earth movement, and the most

²⁰ *Economic Geology*, vol. iii, No. 4, p. 308 (June-July, 1908).

²¹ *Ibid.*, p. 311.

probable derivation that can be suggested for them is that the petroleum was deposited with the clays.

Our experience in drilling wells in the Mexican oil fields has shown similar occurrences of pockets of oil and gas in the highly impervious shales and gumbo, which overlie the oil-bearing limestones and in some cases a thousand or more feet above them. It is true that there is abundant evidence that volcanic forces have been active in this region, as basalt is found in the form of intrusive sills as well as in extrusions in some parts of the field, so that in many cases oil or gas may have come up from the producing beds into overlying strata through fractures caused by this action, but the special occurrences I have here in mind are from wells which are not so related to any of these basalt beds or extrusives as to warrant the belief of such an origin. Furthermore, if they had followed up from below they should be found more abundantly in the sandier and more porous portions of these shales, which is not the case.

In northwestern Colorado and northeastern Utah the Mesaverde beds of the Upper Cretaceous are both coal-bearing and petroliferous. The basal portion of the Mesaverde which carries these deposits is made up of two bands of sandstone separated by a belt of clay shales. This is generally known as the Rim rock in this region.

Going westward from Meeker the coal beds gradually thin, until in the vicinity of Vernal they are no longer of the economic importance of those further east.

A little west of Rangely the sands begin to show indications of oil, and these increase to the westward, until the oil sands acquire very considerable thickness. At one locality an oil or asphaltic sand overlies a coal seam which is seemingly impregnated to some extent with the asphalt.

West and south of Vernal the outcrop of the Rim rock bears northwest to southeast, and the entire thickness of the formation at this point is but a small part of that at Meeker, or even at Rangely. It is also the highest member of the Cretaceous exposed at this place, being directly overlain by the basal beds of the Wasatch, with an entire absence, not only of any trace of the Lewis shale or Laramie, which are found in the eastern portion of these coal fields, but of the upper members of the Mesaverde itself as found further east. Gale says of this at another locality:²²

"It is therefore presumed either that beds corresponding to those now found in the Yampa field had been eroded from the Rangely district and vicinity before the deposition of the Tertiary beds began, or that the uppermost Cretaceous beds were never deposited in the Rangely district. In the latter case, the time during which these later beds were

²² *Bulletin No. 350, U. S. Geological Survey, p. 23 (1908).*

being laid down in other regions was marked by dry-land conditions in this district."

In either event this particular region must have been a land area for a time prior to the beginning of the Wasatch deposition, as is shown by its erosion prior to the deposition of the Wasatch beds and the character of the basal Wasatch conglomerate.

Six miles south of Vernal the exposure of the Mesaverde shows a thickness of 1,100 ft. and is overlain by the Wasatch beds.

Four miles southeast of Vernal, by erosion of the upper beds, less than 600 ft. of the Mesaverde sandstone remain. Of this, the upper 150 ft. of sands as exposed in the Church quarries are rich in bitumen, petroleum residue, evidently a partly exhausted oil pool.

Six miles west of Vernal the Rim rock of bituminous sandstone comes to an end and the Wasatch conglomerates seem to overlap upon the underlying Mancos shale.

The Wasatch, which is in contact with the Mesaverde at the Church quarry, has thick beds of conglomerate and sand rich in oil residue, and many of the pebbles, cobbles, and boulders composing it are worn fragments of the Mesaverde oil or tar sands immediately below. Many of these cobbles are equally rich in bitumen with the Mesaverde oil sands from which they came and richer in oil than the sandy matrix in which they are now imbedded, showing that the Mesaverde at this locality was the exposed edge of an "oil pool" in early Tertiary time when the Wasatch beds were being laid down.

While this cannot be claimed as conclusive evidence of the contemporaneous deposition of petroleum with the Mesaverde sediments, the time limit between the deposition and extrusion is comparatively a short one as measured by geologic units, and the probabilities are, at least, in favor of this assumption.

Like conditions, also, occur in the Arbuckle mountains a few miles south of Sulphur, Okla. Here rich oil sands of the Ordovician were exposed in mid-Carboniferous time. The succeeding and now overlying Carboniferous conglomerates contain bitumen-rich boulders or limestone and sandstone taken directly from the Ordovician beds. Not only were the Carboniferous conglomerates and sands built up by the actual transfer of the bituminous material, but the contact relations of the once oil-bearing Carboniferous sands to the petroliferous Ordovician limestone and sandstone beds below are such as to suggest a strong probability that the Carboniferous beds were enriched by the migration of oil from the Ordovician.²³

The facts brought out by Dr. Orton in his discussion of the theories of transformation, already alluded to, seem also to have a direct bearing on this question.

²³ J. A. Taff: *Tishomingo Folio* and personal communication.

Dr. Newberry's theory that no unusual temperature is needed for the production of oil by his process of "spontaneous distillation" is practically the same as that of more recent writers who, in their advocacy of pressure distillation, suppose that extended periods of time may take the place of that intensity of action which is required in our laboratories for the accomplishment of these results. This theory would imply that if organic substances, such as are petroleum producing, still remain in beds at depths and temperatures comparable to those which have in times past yielded petroleum, then petroleum should still be in process of formation in them. This applies to buried fatty materials just as fully as to other organic matter, if fatty materials are necessarily the fundamental form of matter for the production of petroleum. Furthermore, among the buried strata which have escaped wholly or even partly the effects of geo-dynamic action, there should be beds which would show some of this potential petroleum as imbedded fatty matter, but I know of no such record. So far as we know, the bitumens exist in the rock as such, fully formed, and most other organic matter, even that which may be regarded as "potential petroleum," because it will produce petrolic oils by destructive distillation, or possibly by so-called pressure distillation or geo-dynamic forces, exists as "coalified" carbonaceous material.

Dr. Orton, speaking of the great shale formation of New York, Ohio, Pennsylvania, and Kentucky, says:

"Petroleum is present in all fresh samples of bituminous shale, not potentially, but actually, existing in them as petroleum, and the amount is susceptible of measurement."

"It must not be inferred from these statements, however, that the shales monopolize the petroleum of the bedded rocks of the Mississippi valley. The claim that the limestones are distinctly petroliferous is abundantly established by examination of the various strata. Every important member of the entire scale contains, disseminated through at least portions of its extent, petroleum in large enough amount to admit of measurement. The Trenton limestone, the Clinton, Niagara, Lower Helderberg, Corniferous and St. Louis limestones, each and all furnish conspicuous examples of its presence in noteworthy amount."²⁴

As has been noted, Munn and Murray Stuart make no claims for the contemporaneous deposition of petroleum in any but shale beds, but it would seem that no obstacle intervenes to prevent the extension of this theory to limestones as well, and in this manner include the earlier theory of Hunt, especially if algal remains be recognized as one of the very important factors in the production of petroleum. Dr. David White has called especial attention to the prevalence of algal remains in various oil rocks, and Dr. Clarke has indorsed the suggestion of Bailey Willis,

²⁴ Orton: Kentucky Geological Survey, p. 50.

that some marine limestones have been formed by plant agencies, with the following statement:

"In the shallow seas which are thought to have covered a large part of the North American continent the calcium carbonate may well have been thrown down by algæ. To produce a permanent deposit, however, the water must have been too warm to carry much carbonic acid in solution, and too shallow for the precipitate, while sinking, to redissolve."²⁵

Blackwelder,²⁶ in a recent paper, suggests that the "structures" which form so large a part of the Bighorn dolomite of Wyoming are of algal origin, and notes the strong odor of petroleum emitted by the rock when freshly broken.

Deposition of such petroleum-producing materials as are recorded by Krämer and Spilker and by Potonié, or of petroleum, not only could have been, but evidently has been, made in such seas as this also, and contemporaneous deposition with the consequent limestones is as much a fact as with the shales formed from the muddy sediments observed by them and others.

While many, if not all, of the theories advanced as to the production of petroleum have in them some elements of truth, and while we believe that under diverse conditions petroleum may be and is formed in many different ways, the theory here outlined which recognizes the formation as petroleum under suitable paludal, bog, or marine conditions, at ordinary temperatures, by natural processes, the transformation being accomplished while the organic matter still retains essentially its original character, and its deposition as petroleum with other sediments of its day, seems well supported by observational facts, and its very simplicity and general applicability appear to offer strong grounds for the belief that it will sooner or later come to be recognized as one of the principal methods of the formation and accumulation of petroleum.

In such case, all indigenous or primary deposits of petroleum would be of the same age as the sediments in which they occur and those of secondary or migrating oil would be of different age from the inclosing beds.

²⁵ *Data of Geochemistry*, p. 526.

²⁶ *Bulletin of the Geological Society of America*, vol. xxiv, No. 4, pp. 607 to 624 (Dec. 1913).

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at a meeting of the Institute. If this is impossible then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y. Unless special arrangement is made, the discussion of this paper will close Apr. 8, 1914.

Research with Regard to the Non-Magnetic and Magnetic Conditions of Manganese Steel

BY PROF. B. HOPKINSON, F. R. S., AND SIR ROBERT HADFIELD, F. R. S., LONDON,
ENGLAND

(New York Meeting, February, 1914)

Introduction.—A short time ago Professor Stoughton asked the writer if he would present a paper for the February meeting of our Institute. In reply to this suggestion, some notes have been prepared relating to the subject mentioned in the title. It is to be hoped they may be of interest to our members.

The research now described is the joint work of Prof. B. Hopkinson, F. R. S., and the writer. Those interested in the subject will find further data in a paper entitled *The Magnetic and Mechanical Properties of Manganese Steel*, which will probably be read at this year's May Meeting of the Iron and Steel Institute in London. This paper was submitted to the Institute in October last, and advance copies will shortly be available.

The present paper has been drawn up by the writer on this side the water, and he has not had time to communicate with Professor Hopkinson with regard to the statements or opinions expressed herein. While the writer believes that Professor Hopkinson would in the main agree with the statements herein set forth, it should be understood that apart from the actual work described he is not otherwise responsible.

The experiments described have been carried out on the material known as manganese steel, which one of the writers of these notes discovered in 1883. A paper by him describing this material was read before this Institute in 1893, entitled *Iron Alloys, with Special Reference to Manganese Steel*. It is not necessary to describe manganese steel nowadays; its qualities are so well known, and its use throughout the world is on a very extensive scale.

The Early Use of Manganese Steel.—The writer always looks back and with pleasure thinks of the many willing helpers in this country, who by their encouragement and advice greatly assisted him in testing and introducing manganese steel. As was inevitable with a new material, many practical difficulties had at first to be overcome. Without the help now referred to, and which was so willingly rendered, it would not have been possible to make the great strides which have been accomplished in such a comparatively short space of time. Manganese steel, outside carbon

steel, which has been used for centuries, was practically the first alloy of iron with another element to be produced on a large scale. It will be admitted that since then the work done in this field of alloys of iron with other elements has been of incalculable benefit to the world generally.

The Properties of Manganese Steel.—Probably no other material presents so many curious properties for examination and research as manganese steel. It is hard, and yet it is extremely tough when properly treated; it is naturally non-magnetic, and yet it can be made magnetic; its electrical resistance is very high; its permeability is exceedingly low; in the ordinary way it cannot be machined, yet by proper heat treatment, this difficulty can to a large extent be overcome; in fact many of the specimens referred to in this paper are quite readily machined. Yet the same product in its non-magnetic condition can only be machined with difficulty. Its hardness is most peculiar, because while having only about 200 Brinell ball hardness in its toughened condition, yet it is then almost as difficult to machine as chilled iron. It is very fluid, more like cast iron, yet sets rapidly. Its melting point is comparatively low as compared with mild or medium carbon steel. Although so hard when cold, it can be readily forged, rolled, pressed, or otherwise manipulated while hot.

The Hardness of Manganese Steel.—As regards the hardness of manganese steel, the following experiments may be referred to.

In 1904, one of the writer's licensees rolled a manganese-steel rail. This rail was experimented upon as follows. After 20 min. drilling, 11 g. of manganese steel were removed, while in the same space of time 750 g. were removed from an ordinary carbon-steel rail. A piece of the same manganese-steel rail bent double cold. Its tenacity was 60 tons per square inch, with an elongation of 40 per cent. This is shown in Fig. 1 of the paper on Manganese-Steel Rails, presented at this meeting, and is interesting not only because of the date at which the rail was produced, nearly ten years ago, but because it brings out the point to which the writer wishes to call attention: namely, that notwithstanding the apparently extreme hardness of manganese steel to drilling and other similar tests, its ball hardness is only about 200. In other words, its hardness may be described as "tough hardness," in contradistinction to the brittle hardness of hardened carbon steel with ball hardness numbers of 600 to 800.

Manganese-steel axles and tires were forged and rolled under the writer's direction in 1893. Notwithstanding their extreme toughness under the drop tup tests, they possessed the same peculiar "toughness hardness" to the drill, though the ball hardness was still about the same as that mentioned above for the rail: namely, from about 190 to about 210. The mechanical tests carried out on the foregoing are fully referred to in the writer's paper to this Institute in 1893, previously mentioned.

Making Manganese Steel Magnetic.—In the same paper and the

same date—that is, 1893—the writer pointed out the fact that manganese steel submitted to long heat treatment at about 800° C. in a heating furnace could be made magnetic.

This was further shown in the writer's paper on *The Results of Heat Treatment on Manganese Steel and Their Bearing upon Carbon Steel*, read before the Iron and Steel Institute in 1894. A specimen of manganese steel, marked "C," heated and cooled in a cementation furnace, became considerably magnetic. Dr. Hicks, F.R.S., of the University, Sheffield, was good enough to make for the writer hysteresis curves of this cemented specimen, shown by the full lines in Fig. 1.

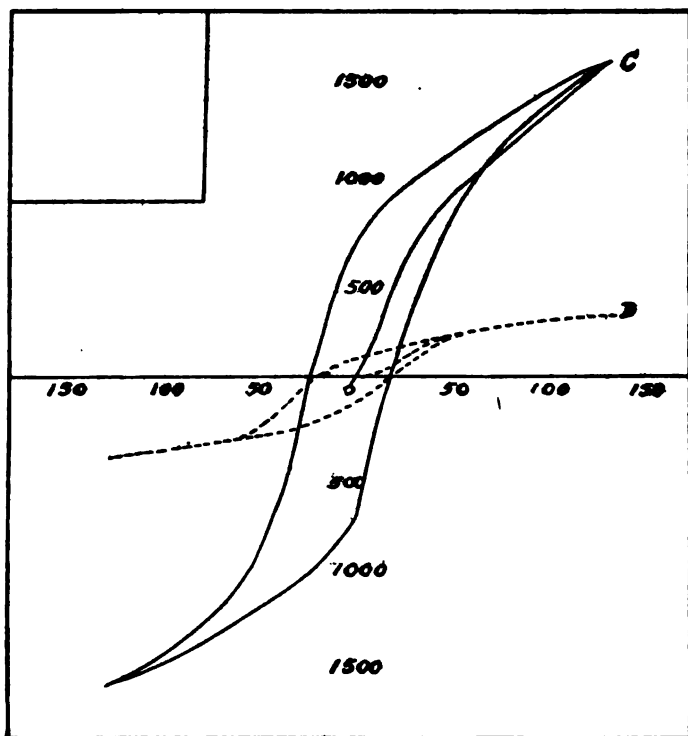


FIG. 1.—HYSTERESIS CURVES.

A specimen of the same manganese steel, marked "D," heated and cooled in a cementation furnace, then water quenched, while magnetic, was much less so than specimen "C." This specimen possessed the hysteresis qualities shown by the dotted curve in Fig. 1.

Another specimen of the same material, marked "F," submitted to cementation, was then forged and water quenched. This became practically non-magnetic like the original specimen "A." In a field of 325 C.G.S., the permeability was 1.08, that is about the same as manganese

steel in its non-magnetic condition and not submitted to cementation.

The above information is fully set forth in the following Table I.

TABLE I.—*The Effect of Cementation upon Manganese Steel*

Mark on Bar	Treatment	Magnetic Qualities	Remarks
A	As rolled.....	Not attracted by the most powerful magnet.	In a field of 320 C.G.C. the permeability = 1.061
B	Similar to "A," but water quenched at about 1,100° C.	Same as "A."	
C	Cemented. No subsequent heat treatment.	Considerably magnetic.	See full curve "C" in Fig. 1.
D	Same as "C," but water quenched.	Much less magnetic than "C."	See dotted curve "D" in Fig. 1.
F	Cemented, forged, and then water quenched.	Practically non-magnetic and like specimen "A."	In a field of 325 C.G.S. the permeability = 1.08.

NOTE: Sample "A" was a specimen of ordinary non-magnetic manganese steel (1.20 per cent. C., 13.42 per cent. Mn.), and from it were prepared, with the subsequent treatment named, specimens B, C, D, and F.

The electrical tests were carried out by Dr. Hicks, F. R. S., of the University, Sheffield.

As stated at the commencement of the writer's remarks, this paper is chiefly intended to present the facts with regard to the relation of the specific magnetism and the hardness of manganese steel on specimens submitted to different kinds of heat treatment. As already mentioned, the more comprehensive paper on this subject, which has been before the Iron and Steel Institute since October last, contains full description of the methods of determining the specific magnetism, taking the heating and cooling curves, photomicrographs of the specimens experimented upon, and other details, so that it is unnecessary to describe them here.

Effect of Treatment on the Non-Magnetic and Magnetic Qualities of Manganese Steel.—As is well known, among some of the many curious features met with in alloys of iron with other elements, are their behavior with regard to magnetic qualities. Manganese steel, while non-magnetic naturally, can be made magnetic. Some of the iron and nickel alloys are also non-magnetic, but by certain treatment—for example, immersion in liquid air—can be made magnetic. While the present joint research by Professor Hopkinson and the writer relates to experiments which have been in progress for about three years with regard to the effect of heat treatment on manganese steel, it may be mentioned that the writer in 1894 read a paper before the Iron and Steel Institute on

The Results of Heat Treatment on Manganese Steel and Their Bearing upon Carbon Steel, in which it was pointed out that by certain heat treatment manganese steel could be made magnetic, also that this quality could be reversed at will; in fact, by means of some of the treatments now described, which produce magnetic qualities, the material can be made so that it can be tooled. A bar of manganese steel which is non-magnetic, either in its brittle or tough condition, can by heat treatment be made magnetic; in fact, its specific magnetism can be increased until it is about half that of Swedish charcoal iron, and no doubt by still longer heat treatment in the specimens now referred to, the specific magnetism can be increased until it is about 60 to 70 per cent. that of Swedish charcoal iron. It may also be of interest to add that the writer has been able to produce in the same bar, one portion absolutely non-magnetic with a mere trace of specific magnetism, and the other end, by heat treatment, so magnetic that the magnet would readily lift it. In the latter condition, the specific magnetism is about 42 per cent. as compared with Swedish charcoal iron.

The experiments referred to in the writer's paper in 1894 aroused a good deal of interest at the time, many of the leading metallurgists taking part in the discussion which arose with regard to the facts noticed in the research in question.

Experiments on Alloys of Iron and Nickel.—Experiments have also been carried out upon alloys of iron and nickel, and these are also shown to possess reversible qualities, but by quite other treatment than that which effects the changes in manganese steel from non-magnetic to magnetic conditions.

The Effect of Low Temperatures.—Increase of temperature renders manganese steel magnetic, but does not apparently affect non-magnetic iron and nickel alloys, or at any rate to the same extent. Low temperature, that is, liquid air temperature, renders the iron and nickel alloys magnetic, but has not the slightest effect upon manganese steel even if the treatment is continued for as long as 18 hours. These are curious facts.

Some confusion has arisen because the non-magnetic alloys of iron and nickel, containing about 22 per cent. of nickel, become magnetic by immersion in liquid air. By some unaccountable means, some scientists came therefore to the conclusion that non-magnetic manganese steel possessed similar qualities. This, however, is incorrect. Manganese steel entirely differs from the iron and nickel alloys in the fact that it cannot be rendered magnetic by immersion in a medium having even lower temperature than that of liquid air. In other words, it does not seem possible to render manganese steel magnetic by reducing temperatures to very low points in the thermometric scale. The only manner in which it can be made magnetic appears to be the heat treatment shown

in the writer's paper of 1894, previously referred to, and also by the treatments now described, which have been made during the last three or four years.

The Results of the Research.—As the subject appears to be one of interest, Tables II and III, showing the various analyses, tests, and other information, are submitted for consideration.

Various specimens of manganese steel of standard type, and from the same billet, were submitted to heat treatment at the temperatures set forth in Table II, which gives the duration of heat treatment in hours, the nature of the medium in which the cooling occurred, the specific magnetism, and the Brinell hardness number of each specimen before and after treatment. In order to afford some idea of the mechanical qualities of the material, there are also shown the results of the bending tests upon specimens $\frac{7}{8}$ by $\frac{3}{4}$ by $1\frac{1}{2}$ in. between the supports. The maximum load given is the breaking load, and the angle of bend is given in degrees. The mechanical tests also show in a remarkably clear manner the difference in physical characteristics between the various specimens, varying from bent double cold, to bends so small as to be scarcely measurable.

Table II shows the magnetic qualities and certain mechanical tests, including ball hardness numbers, of manganese steel in its non-magnetic and magnetic conditions. The results have been arranged in three groups:

(A) Completely or practically non-magnetic (less than 1 per cent. magnetism).

(B) Partly magnetic (1 to 12 per cent. magnetism).

(C) Very magnetic (20 per cent. magnetism and over).

In Table III the same figures have been arranged according to temperatures.

It will be seen that while the specific magnetism of the specimens shown in groups (A) and (B), with the exception of those in group (B) which were heated to 600° C. and the one specimen heated for 48 hr. at 450° C., is very little, certain differences present themselves. The specimens in group (A) may be termed practically non-magnetic; in group (B) there is a tendency for the specific magnetism to increase; in group (C), representing treatment between the critical temperatures of from about 500° to 600° C., the specific magnetism is quite considerable, varying from 20 to 40 per cent. as compared with Swedish charcoal iron of 99.82 per cent. purity, Fe taken as 100. As before mentioned, with sufficiently long heat treatment, there is no doubt this specific magnetism could be further and considerably increased.

One interesting point which comes out very clearly is that with the increase in specific magnetism, specially in the more magnetic material, the Brinell ball hardness numbers rise very remarkably; in fact these

TABLE II.—*Magnetic and Mechanical Tests upon Manganese Steel in its Non-Magnetic and Magnetic Conditions*

Note 1: Analysis of the material:

C	Si	S	P	Mn
1.21	0.22	0.080	0.080	12.36

Note 2: "S.C.I." refers to Swedish charcoal iron of about 99.82 per cent. purity Fe.

Test Piece No.	Specific Magnetism, S.C.I. = 100	Brinell Hardness Number	Bending Test ½ by ½ by 1½ in. between Supports		Temperature in Degrees Centigrade	Specimen Cooled Down in	Duration of Heat Treatment, Hours
			Corrected Load, Maximum in Lb.	Angle of Bend, Degrees			
"A" Completely or Practically Non-magnetic (Less than 1 per cent. Magnetism)							
	0.3	207	.....	180 unbroken	.....	Quenched from yellow heat in water.	No further treatment
5857	0.3	215	10,750	161	300 310 750	Furnace....	168
5970	0.3	267	10,900	21	750	Air.....	1
5971	0.3	277	12,180	29	750	Water....	1
5973	0.3	277	12,890	29	530 750	Furnace...	15
5298	0.2*	337	10,360	8	450	Water....	1
5972	mere trace	339	10,920	11	530 750	Furnace....	6
5402	0.2	340	12,900	12	400	Furnace....	15
5296	0.2*	408	10,080	2	650	Air.....	1
5303	0.2*	418	9,747	2	650	Furnace....	6
5403	0.6	340	11,680	8	400	Furnace....	3
5403	0.6	340	11,680	8	400	Furnace....	12
"B" Partly Magnetic (1 to 12 per cent. Magnetism)							
5872	1.25	217	10,630	124	300	Furnace....	552
5856	1.0	317	14,400	26	300 400	Furnace....	384
5855	1.0	328	12,900	17	300 400	Furnace....	384
5400	1.0	364	11,400	6	400	Furnace....	24
5389	1.2	361	10,770	4	450	Furnace....	12
5399	2.0	387	9,700	2	400	Furnace....	48
5373	2.2	387	9,250	3	450	Furnace....	24
5374	7.0	418	8,270	2	450	Furnace....	48
5749	12.2*	444	7,420	1	600	Furnace....	3
"C" Very Magnetic (20 per cent. Magnetism and over)							
5661	19.8*	418	8,476	1	600	Furnace....	12
5748	20.0	418	8,478	1	550	Furnace....	6
5750	20.4*	351	12,570	11	500	Furnace....	6
5336	24.4*	375	11,130	5	600	Furnace....	24
5658	24.8*	402	11,801	4	550	Furnace....	12
5304	25.8	438	10,140	2	550	Furnace....	24
5369	28.8	351	9,970	3	500	Furnace....	12
5713	29.8*	430	10,270	2	600	Furnace....	72
5327	30.0*	418	11,270	3	600	Furnace....	48
5330	31.4*	495	8,037	1	550	Furnace....	48
5338	34.4	444	7,890	1	500	Furnace....	24
5337	40.2*	438	7,460	1	500	Furnace....	48
5364	42.0*	444	8,200	nil	500	Furnace....	600

* Repeat tests were carried out on these specimens, similar results being obtained.

TABLE III.—*Magnetic and Mechanical Tests upon Manganese Steel in its Non-Magnetic and Magnetic Conditions*

Arranged According to Temperature

Temperature in Degrees Centigrade	Duration of Heat Treatment, Hours	Specific Magnetism S.C.I. = 100	Brinell Hardness Number
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"A"—Completely or Practically Non-Magnetic (less than 1 per cent. magnetism)

300	168	0.3	215
400	6	0.2	340
400	12	0.6	340
450	6	0.2	337
530 Furnace	15	0.3	277
750 Water	1		
530 Furnace	15	trace	339
750 Water	1		
650	3	0.2	408
650	6	0.2	418
750	1	0.3	277
750	1	0.3	277

"B"—Partly Magnetic (1 to 12 per cent. magnetism)

300	552	1.25	217
300	384	1.0	317
300	384	1.0	328
400	24	1.0	364
400	48	2.0	387
450	12	1.2	361
450	24	2.2	387
450	48	7.0	218
600	3	12.2	444

"C"—Very Magnetic (20 per cent. magnetism and over)

500	6	20.4	351
500	12	28.8	351
500	24	34.4	444
500	48	40.2	438
500	600	42.0	444
550	6	20.0	468
550	12	24.8	400
550	24	25.8	438
550	48	31.4	495
600	12	19.8	418
600	24	24.4	375
600	48	30.0	418
600	72	29.8	430

are nearly double as compared with those representing the original hardness of manganese steel, which is about 200.

In view of deductions which may be made from these experiments, it should be pointed out, and as shown by the tables, that it is quite possible to have manganese steel possessing a ball hardness number of even as high as 408, yet the material remains practically non-magnetic—namely, with only 0.20 per cent. of specific magnetism. It would hardly seem as if any support can be claimed by the allotropist from this fact, because it is also possible to have magnetic manganese steel of about the same ball hardness, yet with 30 to 40 per cent. specific magnetism.

In these specimens possessing high percentages of specific magnetism, the hardness in some cases reaches 495, but one of the specimens in group (C) shows a ball hardness number of 444, yet it possesses no less than 42 per cent. of specific magnetism. It might be interesting to state that glass-scratching hardness requires a Brinell hardness number of about 600 and upward.

The Allotropic Theory.—There may be those who will claim that the high specific magnetism noticed in such specimens may be due to the presence of alpha iron. Be that as it may, the writer considers that this cannot very well be reconciled with the fact that as the material rises in magnetic qualities, and assuming for a moment that this is due to the presence of alpha iron, why does the ball hardness rise to the high figures mentioned, in fact in some cases to over 500, which, as just mentioned, is rapidly approaching material having a quality of hardness which would scratch glass.

Effect of Treatment on the Magnetic Qualities of Nickel-Chromium Steel.—It should not be overlooked that, for example, upon quenching alloy steel, such as nickel-chromium steel containing say 0.65 per cent. carbon, this material in its annealed condition has a specific magnetism of 90 per cent., as compared with Swedish charcoal iron 100 per cent., and a ball hardness number of 212. Upon quenching this product in oil at a temperature of 940° C., the material has a ball hardness of 683, and its specific magnetism is reduced to 74 per cent. Table IV shows the different qualities in the (a) annealed, and (b) quenched conditions.

TABLE IV

Condition of Specimen	Ball Test	Specific Magnetism	Residual Magnetism	Coercive Force	Electrical Resistance
(a) Annealed.....	212	90	14,400	17.5	24.2
(b) Quenched in oil	683	74	7,800	43.7	41.9

It will be seen that on the material becoming hard, the specific magnetism, or what may be termed the "magnetic fixability," has fallen about 20 per cent., whereas in the manganese steel referred to in this paper the specific magnetism increases, and at the same time the ball hardness number increases more than 100 per cent. In other words, as will be shown later on in the paper, these differences in magnetic qualities must, so the writer thinks, be ascribed to reasons altogether different from those offered by the allotropist. As the above figures show, remarkable changes have been produced by the treatments referred to, in physical, mechanical, and electrical qualities. The writer would urge these are due rather to changes in the form of the carbon combinations with the iron.

In the writer's paper read before this Institute in 1893, the following was stated: "It is also important by this experiment to have proved that the hardness of manganese steel is independent of its magnetic condition, confirming Mr. Wingham's contention several years ago (*Journal of Iron and Steel Institute*, 1890, No. 1, p. 101) that the beta-iron theory is inconsistent with the facts noticed in magnetizing hardened steel. He rightly asked: How could permanent magnetism in hardened carbon-steel be reconciled with the fact that such material was found so exceedingly suitable for the manufacture of permanent magnets if the iron present in that material was in the beta-form, the latter being supposed to be non-magnetic? If hardened steel is a material in which non-magnetic beta-iron is imprisoned, so to speak, how comes it that such a steel is, of all others, the most suitable medium for articles requiring magnetic retentiveness? Mr. Wingham further added that to make the hypothesis more acceptable it would be necessary to say that 'apparently hardened steel must contain some alpha [or soft] iron.' This of course is quite inconsistent with the facts known. The harder the steel the more pronounced are its qualities of magnetic retentiveness. . . . Conversely, wrought-iron, in which there is supposed to be no iron present in the non-magnetic or beta-form, even if quenched from a high heat, ought to make a good permanent magnet, as all the iron present is supposed to be in the alpha and magnetic state. It is certainly subject to magnetic influence, but otherwise it has just the opposite quality."

The statements in the foregoing citation, while made by the writer so long as 20 years ago, yet to-day seem to have quite as much force in them as when submitted to this Institute.

The allotropist has, so the writer understands, always claimed that when iron takes the beta form it is non-magnetic. In the specimens described in this paper, however, the same manganese steel which is before absolutely non-magnetic, after treatment possesses about 42 per cent. of the specific magnetism of pure iron, and the hardness, instead of decreasing, as it should do, that is if its latter qualities are due to the

presence of alpha iron, rises to the respectable figure of nearly 500 Brinell ball hardness number. On the other hand, the iron and nickel alloy (C, 0.60; Mn, 1.00; Ni, 20.00 per cent.) which is non-magnetic at ordinary temperatures, remains non-magnetic even if heated for a considerable time, about 96 hr., to temperatures of between 300° and 700° C., yet this same material upon being cooled down in liquid air becomes magnetic. Moreover, its hardness, whether in the non-magnetic or magnetic condition, remains low, from 180 to about 250 ball hardness number.

The writer trusts that the deductions to be drawn from the experiments now described will prove of considerable practical and scientific importance. It is also further shown as a result of this research work, which commenced in 1894 when the writer read his paper already referred to before the Iron and Steel Institute, and now further continued during the last four years by Professor Hopkinson and himself, that by this treatment manganese steel can be brought into such a condition that it can be dealt with by tools.

The Relation of Hardness to the Magnetic Qualities.—It must not be overlooked that with regard to ordinary manganese steel, it is possible to have this material with say 200 ball hardness number, also with considerably over 500 ball hardness number, and in between these two conditions, yet in all these states or conditions the material is non-magnetic.

The writer has also made ball hardness tests on the half of a manganese-steel test bar which had been pulled in a tensile machine. The tensile strength was 62 tons per square inch, with an elongation of 52 per cent. on 8 in. The ball test on the unstressed end was 223, and near the fractured portion no less than 540.

While this hardness is produced by quite different treatment from the specimens described in the present paper, it is interesting to note that the hardness of manganese steel can be varied from the comparatively low figure of 223 up to 540, without in any way affecting its non-magnetic condition, even when the material is physically strained. As is well known, in ordinary steel the material often becomes a strong magnet after being physically strained. Manganese steel of the ordinary type, which is non-magnetic, on the other hand can be strained so that its hardness is more than doubled, yet the non-magnetic condition is entirely unaffected.

Interesting results were also obtained by heating manganese steel to a temperature of between about 500° and 550° C. as an approximate maximum. It is possible to then obtain manganese steel which is magnetic and possesses a ball hardness of about 300 to 350; this product can be tooled. By the further heat treatments described in this paper, the ball hardness of the material can be increased to about 500, with between 30 and 40 per cent. of specific magnetism.

The previous research work of the writer bears in an interesting man-

ner upon the foregoing results. In his original paper of 1888 on Manganese Steel, read before the Institution of Civil Engineers, it was stated "Manganese steel of the lower percentages possesses the peculiar advantage of being softened by the following treatment: A specimen heated sufficiently to be seen red-hot in a dark place, on being plunged at this low heat into cold water, becomes sufficiently soft to be easily filed, planed, or otherwise fitted. Hardness is then restored by reheating to a bright red and cooling in air." Similar results were then reported by some of those joining in the discussion at that time.

The writer's attention has been called by his friend Knox Taylor to the interesting and excellent laboratory practice book by Charles Morris Johnson, entitled *Rapid Methods for the Chemical Analysis of Special Steels, Steel-making Alloys and Graphite*. In the chapter on "The Annealing of Steel," Mr. Johnson pointed out more than five years ago that he had succeeded in softening manganese steel by heat treating it at a temperature of 520° to 550° C. He stated that by this treatment a plate could be drilled without sharpening the bit, also the plate was readily drilled without screeching. As an evidence of the correctness of the foregoing, four holes were drilled in manganese steel without resharpening the drill. Plates of the same material were also easily machined in the planer. It was noticed that some of the plates were also very brittle while in this condition.

Mr. Johnson also made some chemical determinations, and found, as the writer has pointed out in some of his previous papers, and as also noticed by Dr. Ledebur and one of his students at Freiberg, Tetskichi Mukai, of Tokyo, in the latter's paper, *Studies on Chemico-analytical and Microscopical Examination of Manganese Steel*, that the condition of the carbon in manganese steel can be largely changed by heat treatment. In the particular case before referred to, Mr. Johnson found that the carbon had changed into what he terms "almost entirely into the perfectly annealed state." The writer of this paper is heartily in agreement with Mr. Johnson's conclusions, as they help to bear out the view he has held for a long time, namely, that the condition of the carbon in manganese steel has an important bearing upon its physical quality. In other words, without seeking to explain the changes noticed by considering whether there has been an allotropic modification of the iron present, the changes in the carbon combinations in manganese steel may account for, or at any rate have an important bearing upon, the changes in its physical and magnetic qualities.

In the same direction, it would be interesting to add the results of the following experiment recently carried out on similar lines to those referred to in the writer's paper some 20 years ago. It was then, as now, noticed that it was possible to make manganese steel magnetic by the following

treatment. This experiment is, however, more specific, with the exact temperatures recorded.

The specimens of manganese steel were heated as follows:

(a) In charcoal to $1,000^{\circ}\text{C}$. and cooled slowly in an electric furnace. This bar, while to some extent magnetic, is not nearly so much so as the material submitted to the standard treatment at 500°C . referred to in this paper.

(b) Another specimen was taken and heated in the same manner to 970°C ., then cooled in furnace to 500°C ., and kept for 69 hours at 500°C . This was very magnetic, fully as much so as any of the specimens referred to in the present research.

It would appear therefore that, as proved by the various experiments referred to in this paper, the mere heating of manganese steel for a long time in charcoal probably does not produce the same results as the specimens dealt with in this research. The heat treatments necessary to obtain the full effect are those referred to in the present paper, and as mentioned by Mr. Johnson in the above quoted reference from his work. In other words, the temperatures quoted by Mr. Johnson appear to be practically the same as those by which Professor Hopkinson and the writer have obtained in the various specimens treated the many curious magnetic and physical changes described in this paper.

The results of these various experiments open a wide field of scientific speculation, and the writer cannot but think the results described in the present paper will eventually be found to help those scientists who are studying the properties or qualities of what are termed magnetism or magnetic forces.

The Excellent Work of Professor Pierre Weiss on This Subject.—For example, the results of the interesting research work by Prof. Pierre Weiss, on The Magnetic Moment of Atoms and the Magneton, described in his paper to La Société Française de Physique, Paris, Jan. 5, 1913, appear to show that this quality of specific magnetism of the metals in the iron group or their alloys, probably depends upon quite other factors than allotropic modifications of the elements present. Professor Weiss claims that in what he terms "Magnetons" he has discovered better methods of explaining magnetic phenomena than by other theories. He appears to consider that the increase of magnetons, with their important bearing upon magnetic qualities, is independent of allotropic or perhaps even chemical modifications.

Moreover, Weiss, to use his own words, and to quote from him fully on this important subject, has made the following statement. "In 1905 Kamerlingh Onnes and myself undertook the determination of the atomic moments of iron, nickel and cobalt, and the molecular moment of mangetite, Fe_3O_4 . For this purpose we compared the magnetization to saturation of these substances in liquid hydrogen, which boils at 20°

absolute scale, at atmospheric pressure, with the known value of this quantity at the ordinary temperature. For iron and nickel the experiment succeeded, and the appearance of the magnetization curves showed that saturation had been reached. For cobalt and magnetite this state was not reached, due doubtless to the potential energy of magneto-crystalline origin preventing complete alignment. We found for the moment of the gram-atom:

Iron.....	12.360
Nickel.....	3.370

We have also investigated the question of the rationality of the relations between the atomic moments, and have reached a negative conclusion. If we had made the comparison with definite numbers, instead of making it with roughly estimated numbers, before making various slight corrections, we would perhaps have been struck with the extreme exactness with which the ratio 11:3 is obtained. We have in fact:

Iron.....	$12.360 = 11 \times 1123.6$
Nickel.....	$3.370 = 3 \times 1123.3$

I shall here anticipate the demonstration which I shall give of the generality of a rational relationship between the atomic moments and shall call the common aliquot fraction 1123.5 the *Magneton*. As the numbers here relate to the gram-atom, 1123.5 will be the magneton-gram. By dividing by the number of Avogadro 68.5×10^{23} , we obtain the magneton itself, that is, 16.4×10^{-23} . This is the moment of a small elementary magnet which will be contained eleven times in the atom of iron, and three times in the atom of nickel. The magnetons of the same atom will be exactly parallel to each other. For cobalt the gap was later filled indirectly by a series of measurements which I asked O. Bloch to make with the alloys of nickel and cobalt (Bloch, thesis, Zürich, 1912). Up to 70 per cent. of nickel we obtain without trouble, saturation at low temperatures, and this quantity varies in a direct line with the percentages. It follows the law of mixtures. In prolonging the line up to 100 percentage of cobalt, we find 8.925 magnetons, that is nine according to the degree of accuracy of the experiment."

He then goes on to define the magnetic moment of a magnet as "the product of the magnitude of one of its poles and their distance; when a body contains several parallel magnets, the resulting magnetic moment is the sum of the magnetic moments composing it."

He further points out that, with regard to the properties of the alloys of the ferro-magnetic alloys, "Many interesting points have been revealed. In solid solutions magnetization to saturation in the neighborhood of the absolute zero varies lineally as a function of the centesimal

composition. The chemical compounds have, on the contrary, their number of the magneton proper. In the ferro-nickel series, the compound Fe_2Ni , whose existence, it may be said in passing, has been really revealed by the magnetic properties, possesses for the entire molecule Fe_2Ni , thirty magnetons. Magnetization to saturation at very low temperatures is represented within the space of 0 to 100 percentage of nickel by two lines, one of which extends from Fe to Fe_2Ni , and the other from Fe_2Ni to Ni."

Weiss also points out that "While we know as yet but little regarding the properties of the magneton, yet the nature of the change or modification found in bodies whose number of magnetons varies with a determined temperature, sometimes with great suddenness, thus making us think of a point of fusion or melting point, appears to be very mysterious and requires in itself special study." He adds "This is not an allotropic transformation in the ordinary sense of the word, since in the case of magnetite (Fe_3O_4) this body shows that the molecule preserves throughout these transformations its general construction with the same number of degrees of freedom. Does this modification require the expenditure of energy? Are there other external characteristics which accompany it? It is possible to give an answer to this last question on one point only. The constant of the molecular field, which expresses the mutual action of direction in the ferro-magnetic bodies, suffers a change in common with the number of magnetons. The correlation between the number of magnetons in the same atom of iron, for example, and the chemical type of compounds in which it figures, deserves to be studied very carefully. Are the chemical forces elementary magnetic attractions? Are the valences in either case similar to magnetons?"

Weiss concludes his paper by stating: "Finally, as we may say, that as the electron shows the new ideas on the irregular and discontinuous structure of electricity, so the magneton marks as analogous evolution in the representation of magnetic phenomena."

What is the Explanation of the Peculiar Facts Noticed?—Coming as these theories do from such an able worker as Professor Weiss, they must in the near future prove of great importance. The writer, however, would point out that chemical modifications or combinations of the constituents of ferro alloys also offer a field in which at any rate a partial explanation seems to be obtained of some of the many peculiar facts noticed in connection with the research now described. For example, the writer thinks that the behavior of carbon in its various forms, as carbides of iron, or carbides of manganese, or both, their dissociation, their combination, probably have more or less important bearing on the many peculiar magnetic changes noticed in the manganese-steel specimens now described.

With regard to some of the foregoing points submitted for considera-

tion, it is also to be noticed that Honda and Takagi, in their recent and most valuable paper upon The Transformation Points of Iron and Steel at High Temperatures (*Revue de Métallurgie*, December, 1913), point out that the disengagement of heat in such transformations is not noticeable, and still more important, they mention that recalescence cannot be attributed, as believed by some, to the polymorphous transformations of the iron, but that it is due to the disengagement of heat produced by the separation of the mixed crystals of iron.

P. Goerens in his paper on The Influence of Thermal Treatment upon the Properties of Strained (écroui) Steel (*Revue de Métallurgie*, December, 1913) has pointed out that in experiments which he carried out upon strained steel, while annealing will restore the original properties of such material, this does not occur so long as the temperature of annealing remains below 520° C. He found this temperature, 520° C., was constant not only for one but various kinds of steel, the temperature of such change varying between 520° and 560° C. This is not a little remarkable seeing that these figures represent about the same temperatures at which the various manganese-steel specimens referred to in this paper become considerably magnetic; for example, the specimens represented by group (C) in Table I.

It must not be overlooked that some of the thermal change points in iron are no doubt due to changes in the specific heat qualities. Weiss points out that the irregularities in the specific heats of ferro-magnetic bodies present veritable riddles, though he considers that, by a proper study and comparison of the magnetic and calorimetric results, a solution appears to be possible.

While fully recognizing how exceedingly valuable free and open discussion on the theories of the allotropist and the carbonist has proved, it would be a great boon if some better understanding could be arrived at as to the meaning of the facts noticed with regard to magnetic phenomena in connection with the alloys of iron and steel. It is admitted that they are very complex, but in the light of the enormous amount of research work which has been carried out during the last few years, it would seem that there is an opportunity for the various schools of thought to meet on some common ground, with a view to work together in that direction which seems to offer the most light, and thus enable us to understand and eventually apply such benefits as are obtained to practical advantage.

Concluding Remarks.—In conclusion, it is hoped that the peculiar behavior now described of manganese steel when subjected to heat treatment, may throw some light upon other phenomena met with in alloys of iron with various elements, including carbon steel, which can also be included as an alloy steel. The experiments have been carried out as carefully as possible, and it has taken several years to deal with and try to unravel some of the peculiar results obtained.

The writer would also here take the opportunity of thanking the willing workers in his own Research Laboratory at Sheffield, Messrs. Milne and Main, for their co-operation and assistance.

Bibliography.—As the publications on this subject are not numerous, a bibliography of those which are probably the most important ones has been added. The writer hopes it will prove useful to those interested.

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DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at a meeting of the Institute. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y. Unless special arrangement is made, the discussion of this paper will close Apr. 1, 1914.

Water Intrusion and Methods of Prevention in California Oil Fields

BY FRANKLYN W. OATMAN, BERKELEY, CAL.

IN order that the conditions which obtain in an oil well may be readily understood, a brief description of a typical California well and a number of the phenomena accompanying same will be given. That the necessity for the exclusion of water be realized, the effects of water intrusion, a description of methods of prevention, and a discussion of causes of failure will be presented, followed by a summary and recommendations.

Fig. 1 shows a section of a typical well which illustrates the relation of oil sands to overlying strata. It indicates a deep water sand separated from the oil sand by shale, and the proper place for the final shutting off of water. In this well a comparatively thick stratum of compact shale protected the oil from overlying water so that the operation of landing the water string was a simple matter. In some wells the protecting stratum may be only from 3 to 5 ft. thick and very careful operation is necessary in order to land the water string of casing properly and not puncture through to the oil sand. The cases just cited are common, but occasionally, after excluding overlying water, productive oil sands are drilled through in the expectation of finding more productive underlying sand, and a water-bearing stratum is tapped. In this case the problem is the reverse of the normal; water must be prevented from ascending rather than descending.

A discussion of well-drilling methods is not within the scope of this paper, except such operations as pertain to shutting off of water. A brief outline of the several conditions which may accompany drilling follows. Some or all may be present in any particular case. The direct relation of these to prevention of intrusion will be discussed in detail further on.

In drilling, the hole becomes more or less irregular in shape, and rough, and as the casing follows the bit into the well it does not fit snugly against the walls. As a result, water may descend between the casing and walls of the well. If a circulation pump is not used during drilling, the hole is simply punched through and the pulverized material removed from the well by means of a bailer. If circulation is maintained there is a continual flow of water down inside the casing and up around the outside between the pipe and the walls of hole. This keeps an open space around the pipe.

It frequently occurs in drilling that a crooked hole results. As a consequence, the casing may press tightly against one side of the hole with considerable free space on the other, permitting only partial circulation, although water may pass slowly between the casing and the compressed earth on the side that is binding.

Alkali water is encountered in many wells in California oil fields, near the surface and at considerable depth. Some of this water is very highly mineralized, containing large amounts of sulphates, and much hydrogen sulphide. In the Coalinga field, for example, a stratum is encountered not so very far above the oil sands, which contains a black, stinking

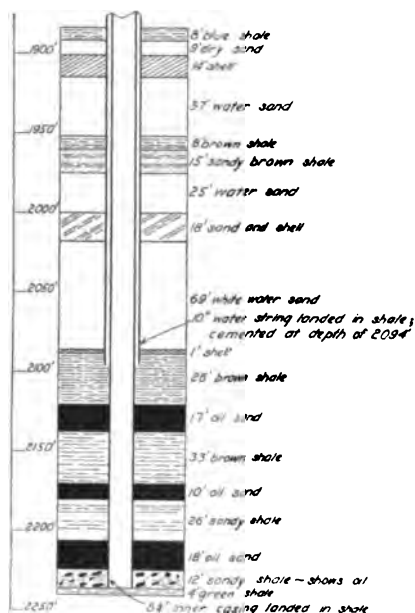


FIG. 1.—PARTIAL LOG OF A TYPICAL CALIFORNIA OIL WELL.

sulphur water. This water is dark colored, heavy with sulphates, and strong in hydrogen sulphide. A number of failures in this field have been attributed to the presence of this water. The relation of such waters to the operation of cementing off will be discussed under failures due to alkali water. Very hot water is struck in some places. Its effect on cement will be considered.

In case oil sand is struck considerable oil may collect in the hole, and later affect the cementing operation. Gas under great pressure may be encountered and tend to bubble up through the water in the well. Opposed to gas pressure is the hydrostatic pressure of the water column in the well.

EFFECT OF WATER INTRUSION

Excluding the water means preventing it from descending or ascending into the oil sands. This must be done to prevent the water from flooding an oil field. In a short time not only the well admitting water to the productive measures but all adjacent wells tapping the same sands would be pumping water and oil. Added to this is the constant menace that the water may increase to such an extent as entirely to displace the oil. In any event, the influx of water forces the gas and oil to rise in the productive measures, thereby causing a serious decline in production.

When water intrudes an oil sand the effect of flooding may be described as follows:

In a new oil field where the gas pressure is high the oil is under pressure, and if water reaches it, the latter descends with difficulty, forming an emulsion.

In an older field where the gas pressure has been greatly reduced the water passes through the sand more readily than the oil. This is because water has less viscosity than oil, and the sand offers less resistance to flow of water. In such a case, the water is believed to flow through regular channels which it forms in the oil sands. A proof of this is offered in the following phenomenon, the experience of a California operator. It became necessary to repair a well, formerly productive, which tapped a rich oil sand. To do this, the casing was filled with water. In a few hours, adjacent wells tapping the same oil sand began to pump water, with very little oil. When the well in question was again put on the beam, it pumped water for some time and gradually the oil increased in amount. The significant fact in this case was that the wells pumped little or no oil, the production being mostly water, although they still tapped a rich oil sand formerly productive. As soon as the water was removed the oil production became normal. From this can be recognized the grave danger to a producing field by flooding.

It sometimes happens that in a region of producing wells a new well may be sunk to the productive sand and abandoned for some reason without proper precautions being taken to prevent water from descending and flooding that sand. The owners of the abandoned well may not be concerned with the effect on adjacent property, but the production of the latter will certainly suffer. Therefore, it is to the interest of all companies in the California oil fields to co-operate and prevent the ruin of their property by flooding resulting from careless operation.

METHODS OF EXCLUDING WATER

As practiced in the principal California oil fields, the methods of excluding water may be classed as temporary and permanent. Perma-

ment exclusion may be obtained by forcing the lower end of a string of casing, called the water string, into an impervious bed above the oil sand; or by placing a water-tight body of cement between the casing and the formation. Of these two methods the first is unsatisfactory and is not to be considered good practice.

Temporary

Regular or special well packers may be employed to prevent temporarily the entrance of water until permanent relief can be found. Such are useful in instances in which the casing may be punctured above the oil sands and water finds entrance to the productive zone through the casing.

Bags of flaxseed, peas, or cereals which swell greatly on absorbing water, forming a compact mass, were formerly introduced in wells to exclude the water temporarily, but are not now used, the cementing method having superseded the use of such.

As a preliminary step to cementing a well in which gas is causing severe agitation, the hole should be bridged by ramming in broken stone, earth, etc. A method successfully used by some operators is to place in the hole a generous plug of the following composition, which has the effect of restraining the gas, temporarily at least. The mixture (parts by weight) is composed of 5 parts red lead, $2\frac{1}{2}$ sand, 2 plaster paris, 2 rosin, and enough boiled linseed oil to make a dense paste. The mass should be allowed to set in the well about 24 hr. before proceeding with cementing.

Permanent

By Use of Drive Shoe.—In sinking a well, a steel drive shoe is attached to lower end of casing. This shoe is slightly larger in external diameter than the casing and has a cutting edge. Before the use of cement it was the custom to land the water string in some compact formation located above the oil measures by forcing the drive shoe into that formation. The well was then continued with a smaller drill, the casing resting on a shelf.

Although this method has been used in some California fields, where certain special conditions obtain, it is not reliable because water generally leaks past the drive shoe and passes into the well. This method may be applied in other fields in which the water string can be landed in an unfractured sticky clay shale.

The drive-shoe method is merely mentioned as a matter of historic interest. The cementing method of excluding water has replaced the former in California, because it has been found to be the only satisfactory one for use in deep wells.

By Use of Portland Cement.—Since the above methods were not always effective, nor of general application, a search for some means to obtain permanent exclusion resulted in the use of Portland cement. It has been used for several years, and when properly manipulated should give the desired result.

The methods in general use for cementing off the water are the tubing, the bailer, and the Perkins. The object of any cementing operation is to obtain a compact collar of cement which will firmly adhere to the casing and so fill all voids resulting from drilling that no water can descend into the oil sands. The operator aims to land the string of casing in a compact bed of shale, which is impervious to water and capable of sustaining the weight of casing.

For example, in the Coalinga field, experience has shown that the blue or brown shale encountered just above the oil sands provides a most suitable final landing place. Note position of this bed as shown in Fig. 1.

Tubing Method.—The following examples illustrate the tubing method of cementing.

Method A.—At the point where the water is to be shut off the hole is reamed out from 4 to 6 in. larger than the pipe for about 40 to 80 ft. from bottom. The water string is raised a foot or so from bottom and water pumped down inside the casing and up to the surface around the outside of the casing. The purpose of this is: To assure the operator that there is free circulation; to wash away the mud, oil, etc., from the sides of the casing and the hole, so that cement may adhere thereto; to open the space around the casing so that a complete ring of cement may form. This water circulation may be continued for a considerable period, sometimes as much as 30 hr. or more, to clean the hole thoroughly. The casing is then raised 2 to 6 ft. from bottom, and a string of tubing (3-in. standard size) with a swedge nipple on the lower end is lowered to within about 2 ft. of the drive shoe. A cast-iron disk, or a packer, fitting close to the inside of the casing, is also on the bottom of the tubing; this is to prevent cement from backing up inside the water string. Cement is then forced into the tubing by a force pump. As soon as all the cement is inside the tubing, a wooden plug is slipped into the tubing, and is forced down on top of and following the cement by the water pump, which now pumps water after the plug to rinse the tubing of cement. See Fig. 2. The pump pressure is usually about 250 lb. when the plug reaches the swedge nipple. Circulation is then stopped, and the operator knows that his tubing is free of cement. The water string is then set on bottom, the casing being spudded into the bottom for a foot or so to prevent cement from rising in it. The well is allowed to stand for a period, varying from 10 to 28 days.

The time of mixing and placing cement varies with the operator. Some companies claim to be able to mix and place all their cement in

from 30 to 40 min.; other companies require an hour or more. The element of time is exceedingly important, as the cement must be placed and allowed to settle before the period of initial set has been passed.

The amount of cement used varies from 2 to 10 tons, according to the practice of the operator and the requirements of a particular case; 3 to 6 tons may be taken as the average amount required.

Cement is mixed with enough water to make the mixture of the consistency of thick gravy, so that it can be readily pumped. Either neat cement or a sand-cement mixture may be used, the former being the most

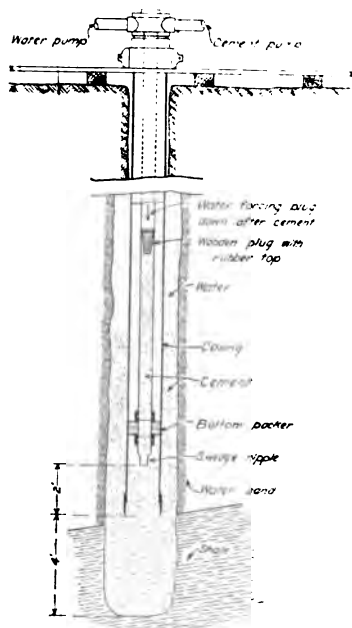


FIG. 2.—THE TUBING METHOD OF CEMENTING WITH BOTTOM PACKER.

favorable. If sand is to be employed, 10 to 15 per cent. may be added when mixing. For neat cement the amount of water added is about 60 per cent. of the weight of the cement.

Method B.—This is practically the same as Method A, but the method of packing the bottom of the casing will be particularly described.

The hole is reamed out and prepared as before. The water string is raised a foot or so from bottom and a string of 3-in. tubing lowered therein. Attached to the bottom of the tubing is a Graham packer. This packer is made of cast iron with outside leather packing and fits snugly against the inside of the casing. It contains a self-closing clack valve opening downward. Projecting from the lower side of this packer are three forked

iron strips, as shown in Fig. 3. The prongs of these forks are compressed and lie in the inside of the casing during descent, but spring out when they pass the bottom of the casing. Then on pulling up they hook on to the drive shoe of the casing, and the operator knows that he has reached the bottom of the hole. A wire fastened to the packer keeps the valve open during descent so that water may enter the tubing. When the prongs are pulled up on reaching bottom, this wire is broken and the valve closes.

When water or cement descends through the tubing the valve can open, but pressure from below will close it. On top of and following the cement is a long wooden plug. Water is pumped down, as before, on top of this plug. When the plug reaches the valve it sticks, and the pump

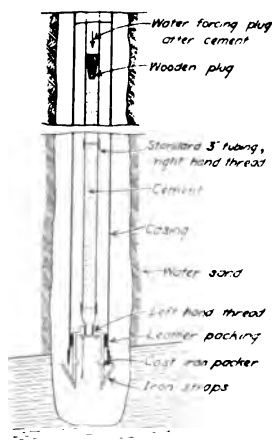


FIG. 3.—TUBING METHOD OF CEMENTING USING GRAHAM PACKER.

pressure rises so that the operator knows that the tube is free of cement. The well is then allowed to stand for the proper period.

There is a left-hand thread between the bottom end of tubing and the packer. The joints of tubing have right-hand thread. To remove the tubing, the string is turned so as to tighten right-hand joints, and this will unscrew it at the bottom.

When drilling is resumed, a few blows from the bit will break the brittle cast-iron packer into small pieces, which soon disappear.

Method C.—This is called the top-packer method. The hole is prepared as before and circulation assured. The casing is suspended from 2 to 6 ft. above the bottom and 3-in. tubing is run in to within 2 ft. of the casing shoe. A packing head is then placed over the top joint of tubing and screwed into the top casing coupling, packing off the space between

the casing and the tubing. When the casing is filled with water and cement is pumped in through the tubing it cannot rise inside the casing and must travel around the shoe and up on the outside.

Bailer Method.—In this method the hole is under-reamed for a distance of about 40 ft. from the bottom and circulation assured. The

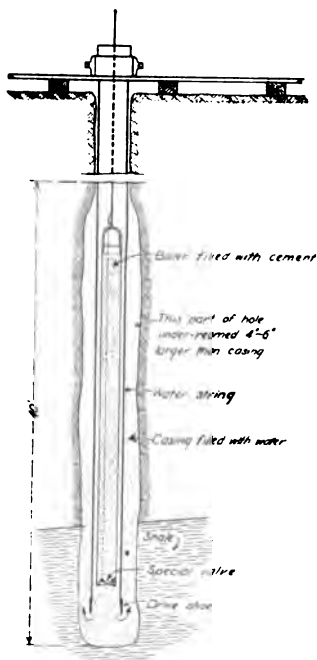


FIG. 4.—THE BAILER METHOD OF CEMENTING.

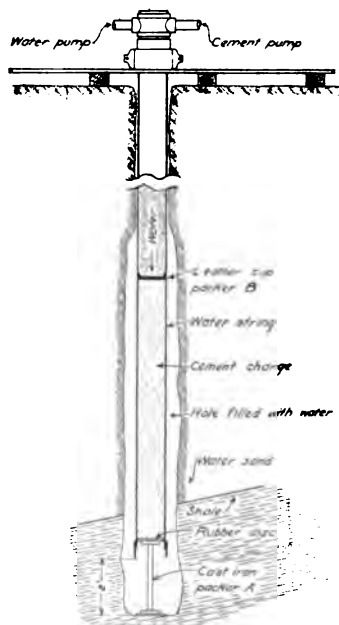


FIG. 5.—THE PERKINS METHOD OF CEMENTING.

water string is then raised about 10 ft. from bottom. The cement is mixed at the surface as before, and placed in a large bailer arranged with a special trap so that it will dump on reaching bottom. Usually two loads of a 40-ft. bailer are deposited in the bottom of the hole. The casing is capped and then allowed to drop, forcing the cement up around the casing and into the bottom formation. On opening a tap and releasing the pressure, the casing sinks to the bottom. It is then spudded into the bedding formation. See Fig. 4.

Some companies bail the cement out from inside the casing before it sets; others allow the cement to set and then drill down through it when extending the hole. The best practice is to bail out the cement if the casing is well spudded into the shale. This dispenses with the necessity of drilling out the cement from the interior of the casing, an operation liable to

fracture the cement collar. Instances have been known where the bailer was tripped while being lowered, but such seldom occur.

Perkins Method.—The Perkins method is similar to the tubing method in results, and has been successfully used in California fields. The following description and reference to Fig. 5 will explain the operation.

Circulation is first made sure of. A cast-iron packer, *A*, with flexible rubber disks at top and bottom, is then floated in the water filling the casing. The cement is mixed and pumped into the casing, forcing the packer down. A leather cup packer, *B*, is placed on top of the cement, and on continuing the pumping the charge of cement is forced to the bottom between the two packers. When the lower packer reaches bottom it stops, while the cement is forced past *A* by bending of the rubber disks. All the cement can be thus forced into the hole outside the casing. When packer *B* reaches packer *A* the pressure rises at the pump and the operator knows that the cement has been placed. Pumping is stopped and the water string set on bottom. The well is allowed to stand for the usual period.

When drilling is resumed, packers *A* and *B* are soon broken by blows from the heavy bit and sinking continued.

DISCUSSION OF CEMENTING METHODS

The success of all cementing methods depends upon the fact that cement grout is heavier than water and displaces the latter. There should be a long collar of cement around the casing, no matter which method is used. The cement collar should extend some distance up the casing. In some cases the cement runs up for only 25 to 40 ft. Instances have been known where it has been forced 400 ft. or more above the shutting off point. The tubing and Perkins methods are similar and have one advantage in that the large amount of cement used coats the casing for some distance above the bottom of the hole. As this coating may be through the water sand, the cement is believed to form an effective protective coating against deterioration of casing by ground waters. The eating away of casing by chemically active waters, resulting in passage of water to the oil sand, is a very dangerous condition in the oil fields. This is a very strong point in favor of tubing or similar methods.

When the cement has been allowed to harden, the well is bailed dry. If there are no leaks at the bottom, or through holes in the casing, a dry well should result. Drilling may then be resumed. If unsuccessful, the hole must be re-cemented; cases are on record where it has been found necessary to re-cement from two to eight times.

Either the tubing or the Perkins method is applicable in the average case. The bailer method may be used in normal cases, and also when it is necessary to block some hole already existing, or in closing a discarded

hole. The drive-shoe method is applicable in a compact sticky shale unfractured by heavy drilling. One of the large California companies claims to have wells in which the water was successfully shut off by use of the drive-shoe method 10 years ago, and which are still water-tight, but these are very exceptional.

Owing to the rapid eating out of pipe in many California fields, due to bad water, it is of the highest importance that as far as possible a thick coating of cement surround the water string. Many operators to-day are advocating the following operation for permanent protection against water intrusion: Sink the 12-in. casing as far as practicable and then cement off by the tubing method, forcing the cement as near to the surface as possible. Then land the 10-in. water string in a suitable bed above the oil sands, cementing again by the tubing method, forcing the cement well up around the pipe. Run in a string of 6-in. casing, land it 2 to 4 ft. below the 8 in., and cement the space between the 6 in. and 8 in. solid. In this case the bottom of the 6 in. is only a few feet below the 8 in. and in the same impervious shale bed. If this method is adopted the second water string is protected by a heavy ring of cement and if properly done the well should last for many years. This method, or a modification thereof to meet special circumstances, will inevitably be adopted in California to meet the demand that absolute, permanent exclusion be secured.

DISCUSSION OF CEMENT AND ITS USE

The necessity for exclusion of water and the methods in general use for obtaining this result having been presented, the causes of failure of cementing operations and means of reducing failure to a minimum will be discussed. The causes of failure may be grouped as physical and chemical. The first group includes features relating to physical conditions in a well, manipulation, and placing of cement. The second group deals with the chemical behavior of cement under various circumstances, notably: Variation of properties of cement by varying the process of manufacture; effect of alkali and hot waters.

In the oil fields the cement used is required to give a very dense, compact mass, rather than great strength, and must be as resistant to decomposition by alkali water as possible. Chemists have thoroughly studied the cement question, and the results of their investigations are summarized below. Free lime must not be present for it endangers the quality of the cement, because reactions between lime, alumina, and sulphates form a compound which on hydration swells and bursts the cement. Therefore a necessary qualification for cement to be used in oil wells is that there must be no free lime, especially if the cement is exposed to strong sulphate waters. Magnesia behaves similarly to lime in reac-

tion, and may hydrate slowly and finally cause disintegration if present in amounts over 8 to 10 per cent. The period of initial set is influenced by the concentration of alumina. An increase in alumina results in a rapid-setting cement. High aluminous cements are, however, severely attacked by sulphate water. Iron oxide is advantageous in cement subjected to strong sulphate waters because it does not react with calcium sulphate as alumina does, resulting in disintegration. Certain iron-ore cements have been shown to be alkali-proof and disintegrate very slowly on immersion in strong alkali water.

Gypsum may be added to regulate the time of setting. Up to about 2 per cent. it retards setting; beyond 2 per cent. it makes the cement quicker setting. The amount of gypsum should be low in a cement to be used in alkali water.

The Setting of Cement.—This is a process of gradual chemical change arbitrarily divided into three periods: (1) Initial set; (2) final set; (3) hardening. The important condition to be observed in cementing a well is that the cement shall be mixed and placed in the well and have time to settle into a uniform mass before the time of initial set. Suppose a well is cemented by the tubing method, and that the cement is forced up around the casing for a considerable distance while pumping. The cement is then allowed to settle, provided no underground currents or gas bubbles keep it agitated. If the time of initial set is passed before the cement settles out to a uniform mass, then a considerable part of the usefulness and strength has been lost. The success of the work now depends on the final set and hardening. At the best, this will result in a less dense and less resistant product, although it may happen that it is sufficient for water exclusion in a given case. Hot or alkali water, excess of water in mixing, and other points which affect the time of setting will be treated further on.

Long storage may increase or decrease time of setting, depending on the composition, particularly as regards amount of free lime. Some cements, though slow setting when made, become quick setting on storage. This has been known to take place within a few days. After longer periods the original slow setting quality may return. Trouble of this kind is characteristic of light burned cement rich in alumina.

The amount of water used in mixing has an important bearing on rate of setting. Up to a certain limit, the more water used the more the time of setting is increased. The limit comes at about 60 per cent. by weight of water, at which point the cement mixture is saturated.

Since in cementing a well by any of the methods previously described a large excess of water is used in mixing, it is evident that the amount of water finally in the mixture when in place is about 60 per cent. In this event the time of both initial and final set has been greatly prolonged beyond the time of setting under normal surface conditions. This fact is

of importance to the operator because the cement has a longer time in which to settle during the period of initial set.

Considerable experimental work has been done by many investigators to determine the effect of various salts on rate of setting. Calcium chloride, CaCl_2 , decreases time of set, and if over 2 per cent. by weight is used is likely to so hasten the set as to make the cement difficult to handle. The use of $\frac{1}{2}$ per cent. of sal soda, Na_2CO_3 , has been found effective in hastening the set in wells troubled with gas.

Since hot water is encountered in many oil fields, its effect on cement is worthy of notice. In general it may be stated that the time of setting decreases with increasing temperature. The following experiment illustrates this:

Neat Cement, 40 Per Cent. Water

Temperature, degrees F.....	84	110	142
Time of initial set, hours.....	6	3 $\frac{1}{2}$	2 $\frac{1}{2}$
Time of final set, hours.....	8	5 $\frac{1}{2}$	3 $\frac{1}{2}$

The temperature of water in oil wells has been known to go as high as 60° C. or more, which corresponds to 140° F. The above results show that at 142° F. the time of setting is less than half what it was for what may be considered the normal temperature.

It is therefore important to know, when cementing a well, whether hot water will be encountered. If so, its effect on time of setting should be considered.

The following table shows the effect of gypsum on time of initial set of cement with 26 per cent. water:

Time of initial set, in minutes:

Amount of gypsum, per cent...	0	1	2	3	6
Sample A.....	4	258	287	268	84
Sample B.....	232	477	460	425	40

The advantage of finely ground cement for oil-well work is a question open to discussion. Fine grinding varies the soundness and rate of settlement. Finely ground cement if composed of particles of different relative size, so as to render the voids negligible, will make a more dense product, less pervious to water. The effect of fine grinding on time of initial set may be well illustrated from the following table prepared by Richard K. Meade.¹

¹ *Proceedings of American Society for Testing Materials*, vol. viii, p. 410 (1908).

No. of Sample	Percentage Passing a No. 200 Sieve					
	75	80	85	90	95	100
	Time of Initial Set, in Minutes:					
1	255	246	192	75	12	2
2	105	106	100	100	22	6
3	120	115	100	95	60	35
4	240	200	182	115	60	30
5	240	210	110	55	15	5

Since cement may have its time of initial set decreased by fine grinding, it may be advantageous to secure such cement for use in oil wells (as those troubled with gas), in which it is desirable to have the cement set rapidly. Finer grinding increases the sand-carrying capacity of cement, which is advantageous in cases where sand is added when cementing a well. The brands of cement most used in California oil fields will pass about 97 per cent. through a 100-mesh screen, and 80 to 85 per cent. through a 200-mesh screen.

Summarizing, finely ground cement should be advantageous in cementing a well, for: It sets quicker, more completely, and is more active; it forms a sounder and more dense mass with greater resistance to action of decomposing alkaline water; it is less permeable to water under high pressure; it can carry more sand. But it costs more, may be harder to procure, and may increase laitance under conditions effective in wells.

ALKALI WATER

Alkali water is encountered in the oil fields of California. In fact most of the water to be shut off is mineralized to a greater or lesser degree. In some places the water is very heavy with sulphates. Reference has already been made to the "Big Sulphur Water of Coalinga" which is claimed to be the cause of a number of failures in that field.

There has been much discussion as to whether most failures are due to presence of alkali water or to physical conditions. The questions asked by oil men are: Will strong alkali water prevent the cement from setting in the well? Will such water cause later disintegration of cement, resulting in failure of the cementing operation?

Let us see if strong alkali water will prevent the proper setting of cement. To do so, consider the case of an ideal well. Suppose that no conditions such as presence of gas, oil, mud, crooked hole, etc., prevail to prevent setting, except that an exceedingly strong sulphate water is to be cemented off. Also, suppose the cement properly placed before the time of initial set. Under these ideal conditions, if the cement fails to set, such failure may be attributed to the action of alkali water. It is

known that the principal injurious substances in such water are sulphates.

Such ideal conditions, except for hydrostatic pressure, were produced in the laboratory. Western State "Cowboy" brand cement, which is much used by oil men in California, was chosen and tested in solutions of sodium sulphate. Solutions of Na_2SO_4 of 1, 5, 10, and 20 per cent. strength were prepared in large beakers holding about a liter. Cement sludges containing 40 per cent. by weight of the above water solutions were mixed. Each was poured through a tube to the bottom of the beaker containing the solution of same strength as was used in mixing it. This was similar to cementing by the tubing method. After setting for 24 hr., the tests were examined. All set perfectly, except that there was considerable laitance on the surface, and that the upper part of the cement was somewhat softer than is normal. This latter may have been due to delay in hardening due to presence of the salts in the water, and to a large amount of water. The tests were examined from time to time. The cement gradually hardened, giving off much free lime, which on oxidation gave a crust of CaCO_3 on the surface. After six weeks, the tests were all about the same in hardness, and showed no visible signs of deterioration. If continued long enough, no doubt the cement immersed in the strong solutions of Na_2SO_4 would have swollen and disintegrated. Tests on briquettes immersed in a 5 per cent. solution of Na_2SO_4 for six months, resulted in complete disintegration of some, and fatal swelling and bursting in others.

The above experiments prove that a good cement will set in a very strong solution of a typical sulphate water, and will harden. If freely exposed to action of such water, however, the cement may disintegrate completely if in a small mass. If cement will set as described above, it should set and harden in the ideal well described. Whether or not the cement may be sufficiently decomposed later by the sulphate water to permit water to work through the mass is a question for further discussion.

If after a well is cemented and allowed to stand for the proper setting period, it cannot be bailed dry inside the casing, but leaks, the operation is a failure. Evidence presented proves that the failure is not due to prevention of setting by the action of the sulphate water. Therefore it must be due to other causes. It is possible that the great hydrostatic pressure of the ground water may be the determining factor in such cases, but I believe that such pressure is much more likely to be effective later on in aiding disintegration.

Cement will likewise set in hot alkali water, although the period of setting is greatly decreased with increase of temperature, as already shown in the discussion on cement.

The disintegrating effect on cement of a large number of salts has been studied, and the cause of disintegration has been explained by Le Châtelier and others. The study of alleged failures due to alkali water is more

difficult in the case of an oil well because of the inaccessibility of the work and the great hydrostatic pressure.

Thorough investigation has revealed the fact that the direct cause of disintegration is the presence of the sulphate ion resulting from presence of such salts as Na_2SO_4 , K_2SO_4 , MgSO_4 , CaSO_4 . Other salts have only a trifling effect, if any. Le Chatelier's theory of disintegration is as follows: When cement hardens, CaO is liberated, which becomes Ca(OH)_2 . This reacts with the SO_4 present in the water to form CaSO_4 , which in turn reacts with the calcium aluminate of the cement to form a lime-sulph-aluminate, which swells greatly on hydration, with great increase in volume, causing disintegration of the cement. The composition of this substance is believed to correspond to a lime-alum: $\text{CaAl}_2(\text{SO}_4)_4 \cdot 24\text{H}_2\text{O}$. The crystallizing force of this substance is enormous.

Le Chatelier states that the extent of the disintegration varies directly as the percentage of alumina present in cement. Cement containing 1 to 2 per cent. of Al_2O_3 is practically unaffected. Cement containing 7 to 8 per cent. of Al_2O_3 swells rapidly and disintegrates. He replaced the alumina in cement by oxides which do not react with CaSO_4 , such as oxides of iron, chromium, and cobalt. The resistance to action of sulphates was then much increased. Iron oxide gives the best effect.

Many analyses have been made of surface alkali waters and their disintegrating effect on cement has been studied. For purposes of comparison typical analyses of strongly alkaline well and surface waters are given. As typical of a strong alkali surface water which has caused great destruction of concrete, the following is an analysis of water from the Sun River project, Great Falls, Mont. The analysis is quoted from an article by J. Y. Jewett.²

Substance	Parts per million
CaSO_4	1,690
MgSO_4	6,870
MgH_2CO_3	305
MgCl_2	192
KCl	20
Total solids.....	9,077
Ignition loss.....	222

An analysis of well water from the "Big Sulphur Water" of Coalinga oil fields is given as typical of those encountered in California which may act upon cement in a well and tend to cause disintegration.

² *Proceeding of American Society for Testing Materials*, vol. viii, p. 480 (1908).

Substance	Parts per million
NaCl.....	1,010
K ₂ SO ₄	170
Na ₂ SO ₄	1,435
CaSO ₄	141
MgSO ₄.....	.....
CaCO ₃	153
Na ₂ CO ₃.....	.....
MgCO ₃	86
Total.....	2,995
H ₂ S.....	Much

It is noticeable that the water of some oil wells is highly mineralized, but in general the percentage of sulphate does not run as high as in the water from Great Falls. There is little doubt but that the water in some wells is rich enough in sulphates to decompose the cement under conditions similar to those acting on the surface. Conditions in a well are favorable to rapid disintegration, since the great hydrostatic pressure tends to force the water into the pores of the cement.

It is quite probable that disintegration of cement does take place, but as an after effect. To further emphasize the fact that strong alkali water has little to do with the original failure, the following case is quoted from the experience of a Coalinga operator.

A failure was reported in which fragments of cement were brought to the surface accompanied by black sulphur water. The cement was said to be "very porous and broken up, as if it had swollen and burst." This may appear to be a case of failure due to disintegration by sulphate, but it later appeared that there was free gas at the bottom of the well. The phenomenon was probably due to action of gas in the well, and will be further discussed under failures due to gas. This is an illustration of a number of failures which have been wrongly credited to action of alkali water.

In summarizing briefly the relation of failures in any well to alkali water, it may be said:

1. Cement will set without regard to concentration of the alkali in water.

2. Conditions appear very favorable for later disintegration of cement, especially as regards effect of pressure, unless retarded by secondary action.

3. With a large sound collar of cement, later disintegration will proceed slowly, because of the size of the collar.

4. The use of alkali-proof iron oxide cement will reduce the chances of disintegration to a minimum; also lime and gypsum should be within the proper limits.

5. Most failures are due to other causes than presence of alkali water.

CIRCULATION

The object of circulating water down inside the casing and up around the outside is to clean out the hole. If the circulation can be made, the operator knows that there is a certain amount of free space around the casing, but this does not prove that the casing is entirely free from contact with the wall. The lower part of the hole is usually under-reamed larger for a considerable distance from the bottom, as explained. This lessens the chances of contact between pipe and ground.

Since the object in cementing is to get a long tight collar of cement entirely inclosing the casing, it is necessary that the pipe be free. When drilling, much fine mud is formed. This must be removed before cementing, so as to leave the casing clean, and to leave the walls of the hole rough and free from sediment. If this is done properly, the cement will then adhere tightly to the casing and completely fill the surrounding space and get the proper purchase. Should there be a coating of oil on the casing, such may be removed by circulation.

If the mud is not properly removed, when the cement is forced through it, the two may be more or less mixed. This is fatal to the proper setting of cement, which may even not set at all.

It sometimes happens during drilling that the hole may get slightly out of line, and so, when cased, the pipe may be in contact on one side, and free on the other. Or blocks of ground may drop in from the wall and press against the casing. When circulating, therefore, the water must dodge these obstacles. It naturally takes the path of least resistance, and so the trouble sometimes is that it wears out a spiral passage through the mud, only partly removing it. Long-continued circulation will tend to increase the size of the channel, which is imperative for success.

Cases are known in which the cementing work was a failure, because of this partial cleaning of the hole. In one instance of failure, the operator, upon pulling the casing and examining it, found a sort of spiral band of cement around and adhering very tightly to the casing. The cement had set well, and was hard, although the water in the well was strongly alkaline. In this case it was evident that the circulating water, instead of washing out all the mud, took the path of least resistance and wore out a channel for itself. Since the cement was forced up in liquid condition, it naturally followed the path formed by water circulation. When it hardened, it only partly filled the original hole, the remainder being occupied by mud. This mud was evidently very pervious to water, which flowed through it to the bottom. Under-reaming and long-continued circulation probably would have made the work successful.

MIXING AND PUMPING OF CEMENT

It is necessary that the cement be placed as soon as possible after mixing. The usual time for the complete operation of mixing and placing

the cement is about one hour. There is a possibility that the initial set will take place before the cement has been pumped, and therefore it is desirable to place it rapidly, so that it will have as long a time as possible to settle completely around the casing before the end of period of initial set. If a good brand of cement is used, the time of setting of which has been previously determined, failure is not likely to occur owing to premature setting if the cement is quickly mixed and placed.

If the cement is mixed by hand, six to eight men can thoroughly mix a batch of about 5 tons in from 10 to 15 min., stirring with hoes. A mixing box 7 by 12 by 2 ft. will hold about 8 tons of cement. Water may be furnished from a large storage tank and run to the box direct, or a line of hose with a small nozzle may be connected to a pump. After the cement is mixed, it is run through a screen into a small tank, with a 6-in. suction to the cement pump. Some operators use the same pump for circulation and pumping the cement; others prefer one for water circulation and another for cement. The type of pump in general use is the 10 by 5 by 12 in. duplex mud pump commonly found in the oil fields. It is connected to the tubing by a section of 2½ or 3 in. pressure armored hose.

If a mechanical mixing machine is used the cement can be more quickly and uniformly stirred than by hand. A continuous mixing machine is to be recommended, because it insures steady flow, reducing the time of placing. A rotary screw mixer is the type suggested. Most cement is hand mixed as described and generally gives satisfaction.

As regards pumping, it is important that the pumps be stopped as soon as the cement charge is placed, so that the charge will act as a unit and the cement will not be required to settle through a long column of water, and so lose its homogeneity. Provision may be made for this by pumping just enough water after the cement to fill the pipe and clear it of cement, the quantity having been previously measured. Or the pump may be stopped when the pressure rises, indicating that the packer or the plug following the cement charge has reached bottom.

Any method which will decrease the time of mixing and placing the cement is highly desirable and every effort should be made to accomplish this in the least possible time.

EFFECT OF OIL AND GAS

In cementing the average well in a field which has been developed to some extent, interference due to the presence of oil or gas is not likely to arise, because the water is cemented off before reaching the productive oil sands. At times minor oil or tar sands are passed through, before reaching the main productive measures, which may affect the cementing operation.

In new fields where the exact relation between water sands and on

sands has not been determined, the productive measures may be drilled through in the expectation of finding more productive ones below, and water encountered instead. To prevent flooding, this water must be excluded, and this is often a difficult operation, especially if the lower water sand is very close to the oil sand. In this case oil and gas may cause great trouble and even prevent cement from setting.

Experiments were conducted to determine what effect oil might have on the setting of cement. To water mixtures of cement, different percentages of heavy crude asphalt oil were added and thoroughly stirred in. It was found that a uniform mixture resulted, and the oil did not tend to separate readily. Tests mixed as above containing 7, 10, and 20 per cent. were poured under water and allowed to set. The time of setting was considerably lengthened, but the cement set, and hardened as in any other case.

A cement sludge containing 40 per cent. water was mixed and poured into a vessel of crude petroleum. This cement set extremely slowly. After 24 hr. it was still very slushy. A second charge was then poured on top of the first and both allowed to harden. After seven days, the cement was removed for examination. There was a distinct joint between the two charges of cement, and they were easily separable. On breaking, the inside of the cement was found to be stained. The oil was intensified in places, giving a spotted appearance. The cement was hard and compact except for the cleavage plane between the two charges.

The results of this experiment show that cement will set immersed in oil, provided there is sufficient water used in mixing. The cement will be permeated by oil. In case a film of oil is spread over a surface, the cement will not attach itself firmly to that surface, because the skin of oil results in the formation of a plane of cleavage. In a well we would not expect the cement to adhere very firmly to the casing or to the sides of the hole if oil were present which could not be removed by circulation. This might result in failure, the water penetrating along the joints formed due to the film of oil, although the main mass of cement set properly and was very impervious to passage of water.

The following notes, taken from an article in *Mining and Scientific Press*, Nov. 4, 1911, Oil-mixed Portland Cement Mortar and Concrete, by L. W. Page, indicate the effect of oil on time of set.

"The times of initial and final set are delayed by the addition of oil, 10 per cent. oil increasing the time of initial set by 90 per cent., and the time of final set by 60 per cent.

"Oil mixed mortar containing 10 per cent. of oil has very little absorption. Under a pressure of 40 lb. per square inch such a mortar is absolutely watertight.

"The above mixtures were made by first making a water paste, then stirring in the oil, which disappeared when mixed for a few minutes."

A number of cases of failure are reported from the oil fields in wells in which gas was present. There is much good evidence to prove that gas is responsible for failures in wells in which it is active. The following experiences, as related by successful oil operators, are of interest as regards the effect of gas.

One company reported: "We believe that the principal cause of the failure of cement to set properly in a body is due to gas working up through it. In a good shale, undisturbed and unbroken by heavy drilling, the failures are few. In a broken or rotten shale the failures are many. The principal cause of failure in this well is gas working up through the bridge placed on top of the oil sand. In a bailer sent down and filled with water in the bottom of the casing, above the cementing job, and brought to the surface, the water will stand normal for about one minute, then will be agitated greatly by releasing gas. This shows that the water is heavily charged with gas, which in this case could only get into the casing by coming through the cement placed. The cement which was taken from the bottom shows a considerable amount of oil also, probably carried up by the gas."

Another operator reported: "It seems probable that gas may bubble up through the cement and form channels. In one case a job failed, there being much gas in the well. A second charge of cement was placed on top of the first and a tight hole resulted. In some cases even a second repetition was necessary for success."

In order to determine how the setting of cement might be affected by gas bubbling through it, the following experiments were performed.

An agitator was made from a glass bottle of quart size. The bottom was carefully cut out, leaving both ends open, and then secured in a vertical position, neck down. Fittings were provided so that a column of gas or air could be drawn through the apparatus, entering at the bottom, where the neck narrowed down to the lip. A 60 per cent. water cement sludge was then placed in the bottle so as to fill it half full, and air blown in at the bottom. This agitated the cement rather violently in the center of the column, but less so near the sides. This agitation was continued for 16 hr. At the end of that time the agitation was not so violent, confined to the central portion of the column, while there was a compact ring of cement around the face of the bottle. There was much light-colored froth at the surface. The pressure of air was slightly increased, and was continued intermittently until 48 hr. passed. The cement was allowed to remain quiet for several days and then the bottle was broken, and a section cut through the cement. There was a conical space in the main mass, the inside being funnel or crater shaped, pointing to a small hole in the bottom. This hole extended through the part of the cement which was formerly in the neck of the bottle. The hole was open at the lower end, but stopped-up at the upper by a soft, mushy mass of dead

cement. Water drained through the hole on opening the bottom end. In the neck of the bottle were two zones of cement of different qualities. One was the usual cement color, and fairly hard, though easily scratched with a knife. The other was very light colored, and so soft as to be easily scratched by the finger nail. The hole extended through the hard part, being irregular in cross section, and crooked. The main mass of cement was banded, forming zones of dark, harder cement, or of light-colored soft stuff, which was very porous. This cementing operation was of course a failure.

Other similar tests were made. In one case the air pressure was not so strong, and the setting power of the cement was strong enough to cause the mass to "freeze" and shut off the air. On cutting this test piece, a hole was found in the lower part which did not extend up beyond the narrow part of the bottle; likewise the zones of "hard" and "soft" cement were found.

In both the above cases, there was considerable porous vesicular froth, like spongy pumice, on the surface. This was light colored and very soft. Reference has already been made to "spongy cement" brought up in a bailer with sulphur water. The operator thought that the cause of the failure might have been disintegration due to sulphates, but it was probably due to agitation by gas, which was present in the well.

The results of the above experiments show that if the gas pressure is sufficient, the cement may be kept continually agitated, and so all cohesion between particles lost, in which case a slush of inert cement results which cannot set. If the agitation be less violent, the cement may set in part, and gas channels form through it, which may even be entirely closed later, as setting proceeds.

In an oil well the gas may be under great pressure, but there is also a great hydrostatic pressure tending to counteract this. If the gas pressure is excessive, it will work its way through the cement. In case of cementing a well in which a hole already exists through which gas may rise, the hole should first be bridged so as to exclude the gas. Then the well should be cemented by one of the methods described.

SUMMARY

Operations for shutting off water include the use of flax seed, etc., packers, the drive-shoe method, and use of cement by any one of several methods. The only method discussed at any length in this paper is the one making use of Portland cement. While the other methods have their application, they have failed satisfactorily to meet conditions existing in California fields.

It is recognized that exclusion of water from oil sands is of paramount

importance, and for this purpose the cementing method is standard practice in California.

The composition of all standard Portland cement is practically the same. All cements in general use must pass standard specifications for composition, strength, soundness, etc. Cements may differ greatly in percentage of certain compounds which they contain. The presence or absence of certain compounds affects the various properties of cement in several ways, some being deleterious. The properties of cement may be greatly influenced by variation of operations during manufacture, such as degree of burning and fineness of grinding, or use of gypsum.

There has been much study given by cement manufacturers to the problem of cementing oil wells, and efforts have been made to prepare special cements for this purpose.

The deleterious effect of alkali water is due to the presence of the sulphates contained in it. When cement hardens, the lime liberated forms calcium sulphate, which results in formation of a calcium-sulph-aluminate or lime-alum. This hydrates to a high degree, with great increase in volume, which may result in the disintegration of the cement. Cement will set in very strong alkali water but may be decomposed later.

For cement to be used in alkali water note the following: There must be no free lime; lime content must be kept low; amount of gypsum added must be a minimum; extent of disintegration varies directly as percentage of alumina, therefore it must be kept low; iron may be used to replace alumina; fine grinding increases soundness.

Setting of cement may be varied by: Composition, thoroughness of grinding raw material, degree of calcination, fineness, age, regulators such as gypsum, amount of water used in mixing, temperature, oil, and presence of foreign salts such as are found in sea water.

When cement is deposited under water, the finer part, which is really the most active if properly combined, may float to the surface and form inert, porous laitance. Cement will set properly in a well, if the interfering conditions are neutralized. Some well waters are much stronger than surface alkali water which have caused failure, and therefore we should expect ultimate deterioration of the cement in a well, to a certain extent. This may be counteracted by chemical process, or the cement may deteriorate so slowly that the wells in a field may be exhausted before water breaks in. Pressure is believed to intensify disintegration by alkali water.

In cementing, circulation is necessary before placing the cement, in order to clean the hole, permit the cement to fill all the space, and to become well bonded to the casing and sides of hole. Circulation should be thorough and long continued, lasting as much as 30 hr., or more if necessary, to clean the hole.

Mixing and pumping are important factors in cementing a well and

must proceed with all due haste. Cement should be rapidly mixed, and placed before the time of initial set has been reached. The cement can be pumped thicker than is now the custom, and therefore less water should be used in mixing. A mechanical mixer is strongly recommended.

Oil does not appear to prevent the setting of cement, nor decrease its strength materially, but it increases the time of setting. It renders cement impervious to water, if stirred in, but may cause surfaces of separation in the cement due to films of oil, along which water may pass.

Gas is probably the chief obstacle to the satisfactory setting of cement. Gas may entirely prevent cement from setting; or it may blow holes through the cement, allowing the main part to set; or the setting power of cement may overcome the disturbing action of gas.

It is possible to regulate the time of setting of cement within safe limits. In a well troubled with gas it may be desirable to hasten the setting by use of regulators such as sodium carbonate or calcium chloride.

The water string must be landed in a bed strong enough to support its weight. The bed should be a thick stratum of shale whenever possible.

Crooked holes are probably the cause of many failures, because such prevent clear circulation, and an even distribution of the cement entirely around the pipe.

The pumping of gas, oil, and sand from a producing well gradually reduces the pressure in the productive measure which aids in supporting the overlying impervious bed of shale in which the water string may be landed. The formation may arch, or it may drop down, enlarging the hole. If the upper beds are thin, they may fracture and water may flow through into the productive zone. As a result, a producing field may be flooded beyond the control of operators. Such a phenomenon is not likely to appear for some time in the California fields, since the gas pressure still remains relatively high.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at a meeting of the Institute. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y. Unless special arrangement is made, the discussion of this paper will close Apr. 1, 1914.

Good Ideas in the Mining Laws of British Columbia and Mexico

BY F. L. SIZER, SAN FRANCISCO, CAL.

(New York Meeting, February, 1914)

THE mining regulations of British Columbia and Mexico present some features which might well be copied in the United States, if we are to have a complete revision of the laws governing mining titles.

1. First and foremost is the "square" location, which would mean the abolition of extralateral rights. This is a condition in both of the countries above named which has seemed to work no hardship upon any one, and certainly the limitation of underground rights by vertical planes through all lines makes a locator's rights clear. In view of the long and costly litigation which has involved so seriously many of our most important mining districts, it would seem to be the part of wisdom to avoid a repetition of similar trouble on titles of lode mining claims, by the enactment of a law similar to that in force in British Columbia.

Objections have been raised by representatives of English companies to the investment of large amounts of money in mining operations in the United States, because of the insecurity of title under the present apex law; and the statement has been made to me personally by one of the largest English operators, that he would never again consent to the purchase of mines in the United States, preferring Mexico with all its revolutionary troubles to the danger of encroachment upon his underground rights by an unscrupulous neighbor.

Without going into further argument as to the desirability of the "square location," it should be sufficient to say to those who are inclined to "let well enough alone" and still stick to the "law of the apex" that there have never been any serious objections raised to this feature of the square location in either British Columbia or Mexico. There are well founded and logical reasons for abandoning the doctrine of extralateral rights since it is so difficult of interpretation; the most natural substitute being a law similar to that of British Columbia, giving to each locator an area 1,500 ft. square.

I would advocate the right to locate adjoining claims of equal extent on either side of the *discovery* claim, on the *strike* of the lode, subject to a reasonable requirement in the matter of work upon them; and in the case of a vein dipping flatter than 45° from the horizon, or in case of a

"deposit," I would also favor the right to locate one additional claim (without actual discovery upon it) on the side toward which the lode or deposit dips.

2. For the official known as Gold Commissioner, in British Columbia, there can probably be substituted a county official or, perhaps, the State Mine Inspector, whose business it shall be to inspect the yearly work done upon all claims held by possessory right. He could pass upon the sufficiency of the work and make suitable record of the same in the county recorder's office. This mode of notification to the public would insure honest work of the full value of \$100 per claim each year, up to the time patent is secured; and some method, copying, in part, the British Columbia law, will probably be desirable.

3. The suggestion contained in the foregoing paragraph presupposes the desirability of "annual work" upon mining claims rather than the payment of a government tax, as is the law in Mexico. This is a point which is worth careful consideration, *before the enactment of any law*. The present disturbed condition of affairs in Mexico is an argument against perpetuating possessory title by means of annual tax paid to the government, though it may be justly said that conditions similar to those in Mexico can hardly arise in the United States.

4. It certainly does not seem wise to adopt what has been done in many of the English colonies: namely, retention of jurisdiction by the government over all mineral lands, as that would amount to a leasing system, and there is a preponderance of opinion adverse to this method among active mining men all over the United States.

In conclusion, I have attempted to discuss only those features of the laws of British Columbia and Mexico which I think would be applicable in the United States, leaving to others who are more familiar with the mining statutes of other countries the presentation of their views.



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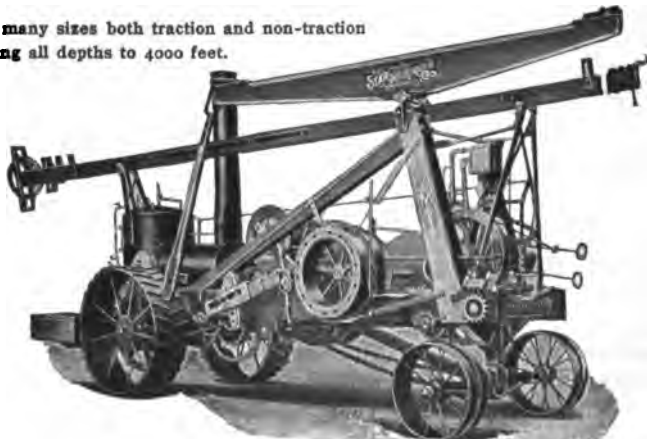
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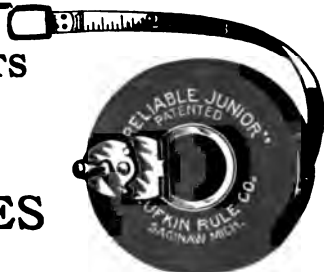
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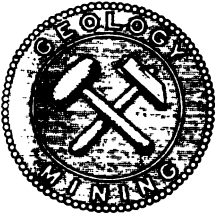
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APRIL, 1914



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One Year's Gains

The table on the following page shows the applications for membership in the Institute received during 1913, analyzed according to States, percentage of increase, and ratio to the mineral output of the State. It will at once be evident that large increases in our membership have been made in some States. In others less progress has been made, and it is clear that results too largely depend on the efforts of a few individuals. Increase of the value of the Institute to each member goes hand in hand with the increase of the Institute in numbers.

If each member will secure one well-qualified new member he will be doing himself a service.

The publications of the Institute have already tripled in volume and have increased manifold in importance. Have you helped, or has it been done for you by others?

Committee on Increase of Membership,

ADOLPH E. BORIE, *Chairman,*

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States	Membership on March 1, 1913	Applications received during 1913 up to Dec. 31	Increase per cent.	Value of 1912 mineral production
Alabama.....	42	4	9.5	\$30,600,000
Arizona.....	104	37	35.0	67,500,000
Arkansas.....	3	0	0.0	6,300,000
California.....	365	32	8.8	92,800,000
Colorado.....	179	19	10.6	58,200,000
Connecticut.....	29	7	24.1	3,000,000
Delaware.....	5	0	0.0	425,000
Dist. Columbia.....	54	19	35.2	300,000
Florida.....	4	0	0.0	9,200,000
Georgia.....	5	0	0.0	6,300,000
Idaho.....	56	12	21.4	21,800,000
Illinois.....	75	9	12.0	123,000,000
Indiana.....	4	4	100.0	42,000,000
Iowa.....	13	0	0.0	23,000,000
Kansas.....	2	0	0.0	26,600,000
Kentucky.....	16	3	18.8	22,400,000
Louisiana.....	2	2	100.0	15,400,000
Maryland.....	11	3	27.3	11,000,000
Maine.....	3	0	0.0	4,600,000
Massachusetts.....	82	14	17.1	6,600,000
Michigan.....	77	7	9.1	80,000,000
Minnesota.....	51	6	11.8	67,000,000
Missouri.....	55	10	18.2	58,300,000
Montana.....	73	44	60.3	71,000,000
Nebraska.....	2	0	0.0	1,500,000
Nevada.....	63	3	4.8	39,000,000
New Hampshire.....	4	0	0.0	2,000,000
New Jersey.....	80	5	6.3	36,800,000
New Mexico.....	29	4	1.4	14,400,000
New York.....	484	66	13.6	38,400,000
North Carolina.....	9	0	0.0	2,800,000
Ohio.....	85	13	15.3	111,200,000
Oklahoma.....	9	4	4.4	53,800,000
Oregon.....	32	1	3.1	2,500,000
Pennsylvania.....	446	66	14.8	445,800,000
Rhode Island.....	5	0	0.0	900,000
South Carolina.....	4	0	0.0	1,600,000
South Dakota.....	16	0	0.0	8,500,000
Tennessee.....	37	9	24.3	19,400,000
Texas.....	36	3	8.3	19,800,000
Utah.....	94	10	10.6	51,000,000
Vermont.....	2	0	0.0	9,000,000
Virginia.....	43	1	2.3	15,000,000
Washington.....	73	15	20.5	15,400,000
West Virginia.....	54	4	7.4	123,800,000
Wisconsin.....	20	13	65.0	14,000,000
Wyoming.....	4	3	75.0	13,400,000

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Dates

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SEC. 1. The membership of the Institute shall comprise four classes, namely: 1. Members; 2. Honorary Members; 3. Associates; 4. Junior Members. * * *

SEC. 2. The following classes of persons shall be eligible for membership in the Institute, namely: as Members, all professional mining engineers, geologists, metallurgists, or chemists, and all persons actively engaged in mining and metallurgical engineering, geology, or chemistry; as Associates, all persons desirous of being connected with the Institute who in the opinion of the Board of Directors are suitable.

As Junior Members, all students in good standing in engineering schools who have not taken their degrees and who are nominated by at least two of their instructors. * * *

Every candidate for election as a Member, Associate, or Junior Member must be proposed for election by at least three Members or Associates, must be approved by the Committee on Membership, as prescribed in the By-Laws, and must be elected by the Board of Directors.

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Erasmus Darwin Leavitt.

BULLETIN OF THE AMERICAN INSTITUTE OF MINING ENGINEERS

No. 88

APRIL

1914

Published Monthly by the American Institute of Mining Engineers at 212-218 York St., York, Pa., H. A. WISOTSKY, Publication Manager. Editorial Office, 29 West 39th St., New York, N. Y., BRADLEY SROUGHTON, Editor, F. O. PINCH, Asst. Editor. Cable address, "Aime," Western Union Telegraph Code. Subscription (including postage), \$10 per annum; to members of the Institute, public libraries, educational institutions and technical societies, \$5 per annum. Single copies (including postage), \$1 each; to members of the Institute, public libraries, etc., 50 cents each.

Entered as Second Class matter January 28, 1914, at the Post Office at York, Pennsylvania, under the Act of March 3, 1879.

SALT LAKE CITY MEETING

The One Hundred and Eighth Meeting of the Institute, for the presentation and discussion of technical papers, will be held at Salt Lake City, Utah, August 10 to 14, 1914.

ALL PAPERS TO BE PRESENTED AT THIS MEETING MUST BE IN THE HANDS OF THE SECRETARY ON OR BEFORE MAY 31, 1914.

PERSONAL

(Members are urged to send in for this column any notes of interest concerning themselves or their fellow-members.)

Members and guests who registered at Institute headquarters during the first half of March:

James C. H. Ferguson, San Francisco, Cal.
Henry Adams, Stamford, Conn.
H. A. Wheeler, St. Louis, Mo.
John M. Sherrerd, Easton, Pa.

Capt. A. F. Lucas, Washington, D.C.
Dexter P. Cooper, New York, N. Y.
L. D. Moore, Chatham, N. J.
Hennen Jennings, Washington, D. C.

R. T. White, formerly General Manager of the Braden Copper Co., Chile, is to take charge of a copper company in Caucasus, South Russia.

Archibald Johnston, First Vice-President of the Bethlehem Steel Co., has returned from China, where he has been for a number of years as a representative of his company.

John A. Savage, Duluth, Minn., formerly General Manager of the Shenango Furnace Co., Pittsburg, resigned March 1, and has associated himself with other engineers under the firm name of John A. Savage & Co., to carry on iron mining and ore-land business.

Dwight E. Woodbridge, of Duluth, is spending a few months in Washington D. C., on professional business.

S. M. Marshall, formerly Chief Engineer of the Cambria Steel Co., Johnstown, Pa., resigned March 1 to become Manager of A. J. Haws & Sons, Ltd., Johnstown, Pa., manufacturers of silica, clay, and magnesite brick.

Charles E. Dinkey, General Manager of the Edgar Thomson Steel Works, of the Carnegie Steel Co., at Braddock, Pa., has been elected President of the Braddock Board of Commerce.

Charles M. Schwab was presented with a loving cup at the formal opening of the new hall at South Bethlehem, Pa., which was donated by Mr. Schwab.

Ferdinand McCann has gone to the Philippines to take charge of the cyanide plant of the Keystone Mining Co., at Auroroy, Masbate.

W. H. Staver is installing a small experimental cyanide plant near the Harvard Mine, Sonora, Tuolumne county, Cal.

A. Van Zwaluwenburg has taken charge of the cyanide mill of the Cia. Minera Natividad in Oaxaca, Mexico.

Dr. Joseph Struthers has become the Second Vice-President of the Johnson Electric Smelting, Inc., New York, which controls the American rights of the Johnson electro-thermic process being developed by the Continuous Zinc Furnace Co..

Berthold Koerting has accepted an appointment as consulting engineer to the Chilean Government and the professorship of mining and metallurgy at the University in Santiago.

Edward C. Morse has resigned from the San Poil Consolidated Co., Republic, Wash.

Earl R. Pembroke has opened an office at 24 East Broadway, Salt Lake City, Utah, as consulting engineer and is to make a specialty of mine examination and investigation of hydro-metallurgical problems involved in the recovery of metals from low-grade refractory ores.

Herbert B. Cox has become associated with the Rickwood Co. of New York, in solving the problem of improved preparation of iron ores.

POSITIONS VACANT

(Under this heading will be published notes sent to the Secretary of the Institute by members or other persons.)

Metallurgist wanted for research in iron and steel. Man with experience in mills preferred. Salary \$4,000. No. 13.

Opening for a few technical graduates to act as instructors in mining to men at the mines under the supervision of the State mine inspector. Salary \$1,800 per year. No. 14.

ENGINEERS AVAILABLE

(Under this heading will be published notes sent to the Secretary of the Institute by members or other persons.)

Mining engineer and metallurgist open for engagement, as superintendent of mines or constructing engineer. Technically educated, with 14 years' experience in United States and Latin America in concentration, amalgamation, cyaniding, constructing. Just finished building large modern all-sliming cyanide mill in Central America. No. 18.

Member, aged 32, married, graduate mining engineer, 10 years' experience as superintendent, mine surveyor, assayer, special experience in opening and developing metal mines and churn-drill work and examinations and reporting, desires position with an operating company or exploration concern. Speaks some Spanish. No. 76.

Member, aged 28, desires position as chief engineer or manager of coal mine. Preferably development of new property. Experience in underground and surface development, design and construction coal preparing and coking plants. An engineer with a splendid record. Over six years chief engineer large West Virginia colliery. No. 77.

Member, aged 40, 16 years' experience, has held position of superintendent with large dividend-paying Western copper mine, and same position with the largest copper producer of South America, open for engagement April 1. No. 78.

Member, aged 42, mining and civil engineer with 20 years' intimate experience in practical problems as engineer for large mining companies, and in general practice on examination, reports, charge of construction, etc., for past six years of that period, desires engagement with mining company as manager or engineer. Best of references furnished. No. 79.

Member, college graduate, aged 38, with 17 years' experience in railroad engineering, construction, general engineering, mining and examination work in coal, lead, zinc and tripoli, in Missouri, Kansas, Oklahoma, Colorado, New Mexico, and Montana, open for engagement as engineer or assistant superintendent. Expert in underground engineering. South America preferred. No. 80.

Member, aged 36, with extensive experience as mining engineer and underground manager for several well-known gold and copper mining companies in Spain, Australia, and South America, open for engagement. Excellent references. Speaks Spanish. No. 81.

Member, aged 31, with experience as engineer, assayer, prospector, and mine superintendent in Mexico and United States, desires position as mine foreman or superintendent. No. 82.

Member, aged 34, graduate engineer, with experience in assaying and mine and mill supervision in Colorado, Utah, and Mexico, desires position as mine or mill superintendent, preferably in Mexico, Central or South America. Speaks Spanish fluently. No. 83.

Member, aged 34, married, with 13 years' experience as chemist, assayer, cyanide metallurgist, and mine engineer and manager in Europe, Asia, and South America. Specialty, the development and administration of iron, manganese, and copper properties. Speaks French, Italian, and Spanish fluently. No. 84.

Member, technical graduate, aged 24, with experience in surveying, sampling, assaying, and general mill work, desires position in mine or mill. Speaks Spanish and French. No. 85.

Member, aged 31, technical graduate, with six years' experience as surveyor and engineer for iron mines in Cuba and South America desires position, preferably in United States. Speaks Spanish. No. 86.

CONGRESS OF MINING, METALLURGY, ENGINEERING AND PRACTICAL GEOLOGY

The Congress referred to in the heading is already well known to our members from its brilliant successes in the past. It is held at intervals of three years and the next Congress will convene at London, July 12 to 17, 1915. All members of the American Institute of Mining Engineers are invited to join the Congress, to take part officially in the proceedings, and to attend the meeting. Applications should be addressed to the Secretary of the Executive Committee of the Congress, care of the Iron and Steel Institute, 28 Victoria Street, London, S. W., where further information may be obtained.

SCHOOL OF MINES, COLUMBIA UNIVERSITY

The School of Mines of Columbia University will celebrate the fiftieth anniversary of its foundation on May 28 and 29, 1914. The program will be as follows:

Thursday, May 28. Evening: Reception in the Gymnasium.

Friday, May 29. Morning: Formal registration, distribution of badges, etc.

11 A.M.: Formal academic exercises in Gymnasium, at which addresses will be delivered by distinguished engineers from abroad and this country, and honorary degrees will be conferred upon certain distinguished graduates.

Noon: Luncheon in the Commons.

Afternoon: Meeting of the various sections of engineering activity—Mining and Metallurgy, Civil Engineering, Mechanical and Electrical Engineering, Chemistry.

Evening: Banquet at the Waldorf-Astoria.

INTERNATIONAL ENGINEERING CONGRESS, 1915

The attention of all engineers is called to the International Engineering Congress to be held in San Francisco in 1915 in connection with the Panama-Pacific Exposition, under the auspices of the American Society of Civil Engineers, American Institute of Mining Engineers, American Society of Mechanical Engineers, American Institute of Electrical Engineers, and the Society of Naval Architects and Marine Engineers.

The sessions will be held in 11 sections and the proceedings will be published in 10 volumes of about 500 pages each, with a somewhat smaller volume containing all general proceedings and an index digest of all papers. The subdivision into sections, with titles of volumes of transactions, is shown in the appended form of application, which may be detached and forwarded with remittance as indicated.

All persons interested are invited to become members whether or not they may be able to attend the Congress.

The membership fee of \$5 will entitle holder to the volume of general proceedings and index digest and to any other single volume according to choice. Other volumes may be subscribed for according to a sliding scale depending upon the number of volumes taken.

The American Institute of Mining Engineers is an underwriter to the general guarantee fund for the necessary expenses of the Congress. Prompt action on the part of members in sending in their subscriptions to membership in the Congress will aid effectively in carrying on the necessary preliminary work without further present financial demands on the Institute for this purpose.

The Committee of Management of the Congress therefore specially requests all members of the Institute to respond promptly with their subscriptions.

APPLICATION FOR MEMBERSHIP

To be detached and mailed with remittance to W. A. Cattell, Secretary, Foxcroft Bldg., San Francisco, California, U. S. A.

The undersigned desires to enroll his name as a member of the International Engineering Congress, to be held in San Francisco, September 20-25, 1915.

Enclosed herewith you will find
(Check—Money Order—Draft)
for \$5.00 in payment of the Membership fee.

In addition to the general Index Volume, I select Volume No. as listed below, as the volume I am to receive for this fee.

INDICATION OF PROBABLE CHOICE OF OTHER VOLUMES:

- | | |
|---|---|
| — The Entire Set | — Vol. VI.. Mechanical Engineering |
| — Vol. I.... The Panama Canal | Vol. VII. Electrical and Mechanical Engineering |
| — Vol. II... Waterways and Irrigation | Vol. VIII. Mining Engineering and Metallurgy |
| — Vol. III.. Municipal Engineering | — Vol. IX.. Naval Architecture and Marine Engineering |
| — Vol. IV.. Railways and Railway Engineering | Vol. X... Military Engineering |
| Vol. V... Materials of Engineering Construction | |

I shall be especially interested in the volumes which I have marked thus: X, and while I do not subscribe for them nor commit myself in any way to do so at a future time, if ordering, they would probably constitute my selection.

Signature

Address

Member of

(Date) 191

LIBRARY

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

AMERICAN SOCIETY OF MECHANICAL ENGINEERS

AMERICAN INSTITUTE OF MINING ENGINEERS

UNITED ENGINEERING SOCIETY

WILLIAM P. CUTTER, Librarian

The Library of the above-named Societies is open from 9 A.M. to 10 P.M. on all week-days, except holidays, from September 1 to June 30, and from 9 A.M. to 6 P.M. during July and August. The Library contains about 55,000 volumes, including sets of technical periodicals and the publications of scientific and technical societies.

Members of the Institute, with few exceptions, are forced to spend a portion of their time in localities isolated from sources of information. To these the Library can render valuable service through correspondence; letters requesting information will receive special attention. The Library is prepared to furnish references and copies of articles on mining and metallurgical subjects; to determine the existence of mining-maps, and to furnish general information as to the geology and mineral resources of all countries.

All communications should be made as definite as possible so that the information received may be what is desired and not include collateral matter which may not be of interest. The time spent in searching for such collateral matter will be saved, and the information will be sent more promptly and in more usable shape.

The members of the Institute can be of service to the Library by forwarding copies of mining-reports, maps privately issued, and similar material, which will be classified, indexed, and made available to other members. Suggestions for additions to the Library, either by purchase or personal solicitation as gifts, will be welcomed. It is hoped that members while in the city will use the Library freely, and assurance is given that most careful service will be rendered to them.

LIBRARY ACCESSIONS

New Books on Mining and Metallurgy

- COPPER HANDBOOK, Vol. XI, 1912-13. By W. H. Weed. Houghton, 1914.
- ETUDE ECONOMIQUE D'UNE AFFAIRE MINIERE. By J. Maurice. Paris, 1914. (Gift of Author.)
- FUEL BRIQUETTING INVESTIGATIONS, July, 1904-July, 1912. Bull. 58, U. S. Bureau of Mines. Washington, 1913.
- HYDRAULIC MINE FILLING: its use in the Pennsylvania Anthracite Fields. Bull. 60, U. S. Bureau of Mines. Washington, 1913.
- METAL MINE ACCIDENTS IN THE UNITED STATES DURING THE CALENDAR YEAR 1912. Technical Paper 61, U. S. Bureau of Mines. Washington, 1913.
- OIL AND GAS PROSPECTS OF THE NORTHWEST PROVINCES OF CANADA. Memoir 29-E, Canada Department of Mines. Ottawa, 1913.

MINE SAMPLING AND VALUING. By C. S. Herzig. With a chapter on Sampling Placer Deposits by C. W. Purington. San Francisco, 1914. (Gift of *Mining and Scientific Press*.)

NOTE.—Mr. Herzig dedicates this treatise to T. A. Rickard, as one who “blazed the way”; but in his Introduction, he justly characterizes Mr. Rickard’s book on “The Sampling and Estimation of Ore in a Mine” as lacking, on the whole, “that continuity of thought which the subject deserves.” This criticism involves no disparagement; for the volume in question was avowedly nothing more than a compilation of articles from a technical journal. Such compilations have been frequently published in recent years. To this class belong, for instance, the Posepny and Emons volumes on Ore-Deposits, the contents of which were gathered from our *Transactions*. Books of this kind are often invaluable for reference; but they cannot take the place of systematic text-books, logically arranged, and bearing throughout the stamp of the critical judgment of a competent author. Such a work Mr. Herzig has undertaken to supply.

Part I, “Mine Sampling,” treats in successive chapters of the principles underlying the sampling and valuation of mines; the preliminary “pick-analysis”; the implements, general methods and precautions involved; the geological factors; churn-drilling as applied in sampling; and the handling, preparation, and assay of samples.

Part II, “Mine Valuing,” similarly discusses the estimation of ore; ore “in sight”; the calculation of profits; the amortization of capital; the writing of reports; “salting”; “prospects”; the determination of specific gravity, etc. A final chapter, by Mr. C. W. Purington, dealing with the sampling of placer-deposits, is one of the most useful in the book.

R. W. R.

New Books on Geology and Mineral Production

ANNUAL REPORT ON THE MINERAL PRODUCTION OF CANADA, 1912. Canada, Department of Mines, Ottawa, 1914.

ELENCO DELLE PRINCIPALI MINIERE, TORBIERE, OFFICINE METALLURGICHE E MINERALURGICHE. Roma, 1913. (Gift of Ministero di Agricoltura, Industria e Commercio.)

MINERAL RESOURCES OF THE PHILIPPINE ISLANDS, 1912. Manila, 1913.

PRELIMINARY REPORT ON THE MINERAL PRODUCTION OF CANADA, 1913. Canada, Mines Department, Ottawa, 1914.

STATISTISK AARBOK FOR KONGERIKET NORGE, 33^{te} AARGANG, 1913. KRISTIANIA, 1914. (Gift of Norway Statistiske Centralbyraa.)

New Books on General Subjects

XII. ALLGEMEINEN DEUTSCHEN BERGMANNSTAGE IN Breslau, 1913. Festschrift. Band I-V.

———Anlage Band I-III, V. N. p., 1913. (Gift of Allgemeine Deutschen Bergmannstage in Breslau.)

BRAZIL IN 1912. By J. C. Oakenfull. London, 1913. (Gift of Pan American Union.)

POCKET GLOSSARY OF ENGLISH-GERMAN, GERMAN-ENGLISH TECHNICAL TERMS FOR ENGINEERS AND MANUFACTURERS. By J. G. Horner. London, 1913.

RADIUM. Hearing before the Committee on Mines and Mining, House of Representatives, 63d Congress, 2d Session, on H. J. Res. 185 and 186. Washington, 1914. (Gift of Committee on Mines and Mining.)

Trade Catalogues

AMERICAN SPIRAL PIPE WORKS, Chicago, Ill.

Pamphlet No. 38. New forged steel fittings.

LEFFEL, JAMES & Co., Springfield, O.

Booklet No. 128. Engines and boilers.

LESCHEN, A. & SONS ROPE Co., St. Louis, Mo.

Leschen’s Hercules, March, 1914.

SPARTA IRON WORKS Co., Sparta, Wis.

Well-drilling and prospecting machinery and tools.

MEMBERSHIP

NEW MEMBERS

The following list comprises the names of those persons who became members during the period Mar. 1 to 15, 1914:

Members

- ADAMS, JOHN H., Cons. Engr. First National Bank Bldg., Birmingham, Ala.
 ALEXANDER, WILLIAM H., Miner 80 Maiden Lane, New York, N. Y.
 AUSTIN, EDGAR TAYLOR, Asst. Smelter Supt., Mond Nickel Co., Ltd.,
 Coniston, Ont., Can.
 BAKER, DANIEL, JR., Asst. Treas., Standard Lime & Stone Co.
 524 Equitable Bldg., Baltimore, Md.
 BALL, MAX WAITE, Geologist U. S. Geological Survey, Washington, D. C.
 BARREN, HARRY B., Supt. Blast Furnaces, Inland Steel Co., . . . Indiana Harbor, Ind.
 BAUMANN, HENRY N., JR., Amalgamator 365 Lynn St., Seattle, Wash.
 BLACK, THOMAS B., Min. Engr. Care Vulture Mines Co., Wickenburg, Ariz.
 BRADY, HARLAN H. 429 West 117th St., New York, N. Y.
 CLARK, EUGENE B., Vice-Pres. and Genl. Mgr., American Smelting Co.,
 207 Railway Exchange, Chicago, Ill.
 COBELDICK, W. MORLEY, Met. Chem., Wallaroo Smelting Works,
 Wallaroo, So. Australia.
 CORSE, WILLIAM MALCOLM, Met. Executive 106 Morris Ave., Buffalo, N. Y.
 CREIGHTON, GEORGE WATSON, Supt., Blooming and Rail Mills, Penna. Steel Co.,
 Steelton, Pa.
 FABIAN, FRANCIS GORDON, Min. and Cons. Engr., 220 West 42d St., New York, N. Y.
 FELLOWS, AUBREY, Supt. Sulphate Plant,
 St. Louis Smelting & Ref. Co., Collinsville, Ill.
 FEUST, ARTHUR, Min. Engr. 462 East 138th St., New York, N. Y.
 FOUST, THOMAS BLEDSOE, Genl. Supt., Warner Iron Co., Cumberland Furnace, Tenn.
 FOVARGUE, FRANK HENRY, Min. Engr. Terlingua, Texas.
 FURST, EDWARD W., Chairman, Ore Dept., Grasselli Chemical Co.,
 784 Arcade, Cleveland, Ohio.
 GILMORE, LUTHER ELMER, Chief Chem., Stanley G. Flagg & Co., Pottstown, Pa.
 GREENWAY, JOHN C., Mgr., Calumet & Ariz. Copper Co. Warren, Ariz.
 HALL, HARRY E., Min. and Cons. Engr. 220 West 42nd St., New York, N. Y.
 HAMILTON, LESTER ANDREW, Supt.,
 Merchant Mill Dept., Penna. Steel Co., Steelton, Pa.
 HARRISON, EDWARD J., Mill Supt., Cons. Ariz. Smelting Co.,
 Box 138, Humboldt, Ariz.
 HENROTIN, CHARLES MARTIN, Mine Operator . . P. O. Box 593, Haileybury, Ont., Can.
 HERRESHOFF, JAMES BROWN, JR., Tech. Director, Nichols Copper Co.,
 524 Beech St., Richmond Hill, N. Y.
 HOVER, DAVID L. C., Chem., A. S. & R. Co., 18 Tenth St., N. E., Washington, D. C.
 HULST, GEORGE POWELL, Supt., International Lead Ref. Co.,
 151st and McCook Sts., East Chicago, Ind.
 HURSH, ROBERT, Min. Engr., Ore Buyer,
 Empire Zinc Co., 703 Symes Bldg., Denver, Colo.
 JOHNSTON, FREDERICK A., Supt., A. & M. Division, S. S. White Dental Mfg. Co.,
 Prince Bay, Richmond Co., N. Y.
 KEEFER, WILLIAM W., Pres. Pittsburg Terminal R. R. & Coal Co.,
 Wabash Bldg., Pittsburg, Pa.
 KEEN, CORNELIUS D., Min. Engr., 806 Commercial Natl. Bank Bldg., Shreveport, La.
 KUCKS, OSCAR M., Acting Supt., Int. Smelt. & Ref. Co. Tooele City, Utah.
 LATHAM, EVERETT BODINE, Chief Geol., Kern Co. Oil Protective Asso.,
 P. O. Box 53, Taft, Cal.
 LAWRENCE, LOVELL, Mill Supt. and Min. Engr.,
 Cheever Iron Ore Co., Port Henry, N. Y.
 LUPTON, CHARLES T., Geol. U. S. Geological Survey, Washington, D. C.
 McHUGH, PHILIP M., Mgr., Dorr Cyanide Mach. Co.,
 730 First National Bank Bldg., Denver, Colo.
 MARBLE, RALPH N., JR., Min. Engr. . . . Mahoning Ore & Steel Co., Hibbing, Minn.

MOLENGRAAF, DR. GUSTAF ADOLF FREDERICK, Prof. Geol., Technische Hoogeschool, Delft Vorstrast, 60, Delft, Holland.	
NOLD, HARRY E., Min. Engr.	Pocahontas, Alta., Can.
NORCROSS, FRED STEPHENSON, JR., Supt. of Mines, B. C. Copper Co., Greenwood, B. C.	
PEMBROKE, EARL RICHARD, Min. Engr.	24 E. Broadway, Salt Lake City, Utah.
PHILPOTT, ROYDEN CAMPBELL, Min. Engr.	Box 655, Guayaquil, Ecuador, S. A.
PIGOTT, CURTIS, Met.	A. S. & R. Co., East Helena, Mont.
ROUDABUSH, MARTIN A., Jr. Topographer, U. S. G. S.	Osterburg, Pa.
SCHMIDT, HERBERT EDGAR, Asst. Chief Engr., Min. Engr., Mahoning Ore & Steel Co., Hibbing, Minn.	
SCOTT, ARCHIE, Chem., Cons. Ariz. Smelting Co.	Humboldt, Ariz.
SEMPLE, ROBERT ALEXANDER, Min. Engr.	Virginia City, Mont.
SMITH, HORACE H., Alaska Gastineau Min. Co.	Juneau, Alaska.
STAHL, CHARLES RAYMOND, Min. Engr.	Stotesbury, Raleigh Co., W. Va.
STIEBEL, HERBERT JOSEPH, Min. Engr.	Bingham Canyon, Utah.
STOLLER, FREDERICK EDWARD, Min. Engr.	W. & L. E. C. M. Co., Dillonvale, Ohio.
SPEERY, ROGER SHERMAN, Min. Engr.,	21 Cooke St., Waterbury, Conn.
STOCKWELL, RUPERT KENNEDY, Chief Engr., Braden Copper Co., Rancagua, Chile, S. A.	
TAFF, JOSEPH A., Geol.	712 Flood Bldg., San Francisco, Cal.
TRIPLETT, WALTER HOWELL, Engr., Moctezuma Copper Co., Pillares de Nacozari, Sonora, Mex.	
VERNON, JOSEPH ANGIER, Mining ...	Oriental Cons. Mining Co., Unsan, Korea.
WALTMAN, WILLIAM D., Genl. Mgr., Franco Wyoming Oil Co.	Casper, Wyo.
WARRINER, JESSE B., Chief Engr., Lehigh Coal & Navigation Co.	Lansford, Pa.
WATKINS, JOEL HILL, Geol.	1320 Penna. Ave., Washington, D. C.
WESTON, CHARLES V., Genl. Mgr., Mascot Copper Co.	Dos Cabezas, Ariz.

Associate

BATTIN, WILLIAM FREDERICK, Certified Public Accountant, P. O. Drawer 1387, Butte, Mont.	
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Junior Members

ANDERSON, ROBERT JOHN, Student.	7608 Harvard Ave., S. E., Cleveland, Ohio.
CALLEN, ARTHUR SPENCER, Student.	453 Chestnut St., So. Bethlehem, Pa.
FRANCIS, CHARLES W., Student.	155 So. Main St., Bethlehem, Pa.
GOUNDIE, JOSEPH KALBACH, Student.	1426 Walnut St., Allentown, Pa.
JORDON, RICHARD DUDLEY, Student.	541 Seneca St., So. Bethlehem, Pa.
LENKER, HAROLD EDWIN, Student.	155 So. Main St., Bethlehem, Pa.
LONG, JAMES SCOTT, Student.	Taylor Hall, So. Bethlehem, Pa.
MICKEL, ROBERT ELI, Student.	541 Seneca St., So. Bethlehem, Pa.
WUENSCH, CHARLES ERB, Student.	Colo. School of Mines, Golden, Colo.

CANDIDATES FOR MEMBERSHIP

The following persons have been proposed during the period Mar. 1 to 15, 1914, for election as members of the Institute. Their names are published for the information of members and associates, from whom the Committee on Membership earnestly invites confidential communications, favorable or unfavorable, concerning these candidates. A sufficient period (varying in the discretion of the Committee, according to the residence of the candidate) will be allowed for the reception of such communications, before any action upon these names by the Committee. After the lapse of this period, the Committee will recommend action by the Board of Directors, which has the power of final election.

*Members***Harry McCammon Alley**, Wonder, Nev.

Proposed by E. E. Carpenter, E. S. Cunningham, E. G. Spilsbury.

Born, 1886, McCammon, Idaho. 1901-05, Salt Lake City High School. 1906-10, Utah State School of Mines; B. S. 1910-11, Solution man, Gold Springs Min. Co., Gold Springs, Utah. 1911 (spring and summer), Engineer, Uncle Joe Min. Co., Virginia City, Mont. 1911-13, Shift boss, Churchill Mill. Co., Wonder, Nev.

Present position: 1913 to date, Foreman, Churchill Mill. Co., Wonder, Nev.

Philip P. Baily, Montreal, Canada.

Proposed by John B. Porter, A. Stansfield, John W. Bell.

Born, 1890, Watford, England. 1904-09, English Public School, at Malvern College, Worcestershire, Eng. 1909-13, Min. Engineering Course, at McGill Univ., Montreal; B. S. 1912-13, Field season with Canadian Geological Survey, as Asst. Geologist.

Present position: Dawson Fellow in Mining, McGill Univ., Montreal.

Fred Sherman Baker, Unsan, Korea.

Proposed by Alf Welhaven, Thomas L. Van Ess, J. B. Lower.

Born, 1886, Columbia City, Ind. 1893-1900, Grammar School, Columbia City, Ind. 1900-04, High School, Columbia City, Ind. 1904-05, Purdue Univ., Lafayette, Ind. 1908, Apprentice, Oriental Cons. Min. Co.

Present position: 1913 to date, Foreman, Tabowie 80-stamp mill.

August Hector von Bayer, Ashland, Ky.

Proposed by W. H. Blauvelt, E. C. Witherby, J. D. Pennoek.

Born, 1873, Baden, Germany. 1880-87, Public Schools, Washington, D. C. 1887-90, High Schools, Washington, D. C. 1890-92, Cornell Univ., Ithaca, N. Y. 1896-1900, Cornell Univ.; C. E. 1900-02, Asst. to Constructing Engineer, building of by-product oven plant at Ensley, Ala., by Semet-Solvay Co. 1902-06, Asst. Engineer in charge of construction of by-product oven plant at Tuscaloosa, Ala., by Semet-Solvay Co. 1906-12, Supt. of Tuscaloosa Plant, Semet-Solvay Co. 1912-13, Constructing Engineer in charge of construction of by-product coke oven plant. Detroit, Mich., by Semet-Solvay Co.

Present position: 1913 to date, Supt. Kentucky Solvay Coke Co., Ashland, Ky.

Julius G. Bergman, Morenci, Ariz.

Proposed by David Cole, W. D. Thornton, L. D. Ricketts.

Born, 1880, Sweden. 1889-96, Elementary School in Hernosand, Sweden. 1900-01, Special student at Royal Technical High School in Stockholm, Sweden. 1901-04, Hernosand's Technical School; M. E. 1899-1900, Machinist Bolinders Mekanisko Verkstad, Stockholm, Sweden. 1905, Electro Dynamic Co., Bayonne, N. J. 1905, Henry R. Worthington, Harrison, N. J. 1905-06, McIntosh, Seymour & Co., Auburn, N. Y. 1906-07, Union Iron Works, San Francisco, Cal. 1907-10, Charles C. Moore & Co., San Francisco, Cal. 1908-10, as Consulting Engineer in San Francisco. 1907, Southern Pacific Railroad Co. 1910, Western Engineering & Construction Co., San Francisco, Cal. 1910-11, Cananea Cons. Copper Co., Cananea, Son., Mexico. 1911-12, Ray Cons. Copper Co., Hayden, Ariz.

Present position: Chief draftsman, Concentrator No. 6, Arizona Copper Co., Morenci, Ariz.

James Frederic Brown, 2nd, New Haven, Conn.

Proposed by J. F. McClelland, Joseph W. Roe, L. W. Bahney.

Born, 1891, Denver, Colo. 1912, Sheffield Scientific School, Yale Univ.; Ph. B. 1914, Candidate for degree of E. M.

Present position: Student at the Sheffield Scientific School, Yale Univ.

William Arthur Butchart, Denver, Colo.

Proposed by David Cole, W. D. Thornton, L. D. Ricketts.

Born, 1867, Benton Harbor, Mich. 1900-01, Min. Mach. Business, Mexico. 1902-03, Mgr., Waters-Pierce Oil Co., Mexico. 1904-07, Mgr., Mine & Smelter Supply Co., Mexico. 1908-09, Construction work, irrigation project, Sinaloa, Mexico. 1910, Removed from Mexico to Los Angeles. 1911-14, Invention and development of the National concentrating table and system of riffing.

Present position: Introduction and sale of above apparatus.

George Holmes Carnahan, El Paso, Texas.

Proposed by Robert H. Cromwell, Robert S. Towne, Edward L. Dufourcq.

Born, 1879, Cadiz, Ohio. High School, supplemented by private study of technical subjects. 1896, Miner and Assayer, Leadville, Colo. 1897, Mine Foreman, Sombrette Min. Co., Mexico. 1899, Shift boss and leasing, Leadville, Colo. 1900-01, Engineer in charge of exploration and development work for the Ecuadorian Association, Ltd., Ecuador. 1902, General Foreman, Mexican Lead Co., Monterey, Mexico. 1903-05, Supt. in charge of the mines of the Cia. Metalurgica Mexicana, Coahu., Mexico. 1906-12, General Supt. of the Montezuma Lead Co., Santa Barbara, Chih., and of mining properties of Cia. Metalurgica Mexicana at Sierra Mojada. Concepcion del Oro, San Luis Potosi, Flojonales.

Present position: Manager of the Teziutlan Copper Min. & Mill. Co., The Montezuma Lead Co., with general supervision over the mines of the Cia. Metalurgica Mexicana.

Frederic Herbert Bertemps Claudet, London, England.

Proposed by H. Hayman Claudet, A. G. Charleton, Edward Hooper.

Born, 1889, London, England. 1904-08, Tarbridge School, Kent, England. 1908-11, Cambridge Univ.; B. A. 1911-13, Pupil in Fraser & Chalmers Engineering Works, Erith, England.

Present position: 1913 to date, Director of F. Claudet, Ltd., Assayers, 6 and 7 Coleman Street, London, E. C., England.

Charles Rolland Conkey, Ontario, Canada.

Proposed by George H. Warren, Frank M. Warren, R. M. Bennett.

Born, 1886, Minneapolis, Minn. General and High School education acquired in Fort Dodge, Iowa, and Minneapolis, Minn. 1905-10, School of Mines, Univ. of Minn.; E. M. 1909, Asst. Chemist, A. S. & R. Co., Chihuahua, Mexico. 1910-12, Mining Engr., Oliver Iron Mining Co., Eveleth, Minn. 1912-13, Mining Engineer, Menden Iron Co., Hibbing, Minn.

Present position: Structural Draftsman, Barnett & McQueen Co., Canada.

Robert Nathaniel Copeland, Llalagua, Bolivia, S. A.

Proposed by Durward Copeland, H. A. Buehler, G. H. Cox.

Born, 1888, Chelsea, Mass. 1903-07, Chelsea High School. 1907-11, Missouri School of Mines; E. M. 1911-12, Underground Mines, Vinegar Hill Zinc Co., Wis. 1912-13, Asst. Supt. of Vinegar Hill Mine, Galena, Ill. Same company as above. 1913-14, Supt. of Vinegar Hill Mine. 1913-14, Mine Supt. for the Compania Estanifera de Llalagua, Bolivia.

Present position: Mine Supt. for Compania Estanifera de Llalagua, Bolivia.

Daniel Cushing, Cleveland, Ohio.

Proposed by Thomas H. Beddall, Thomas L. Watson, L. W. Bahney.

Born, 1883, Lowell, Mass. 1902-03, Univ. of Virginia. 1909-10, Univ. of Virginia, Min. Engineering. 1910-12, Yale Univ., Min. Engineering. Grad. from Yale; Ph. B. 1904-05, Construction work. 1905-07, Daniel Cushing & Co., Lowell, Mass., Sheet Metal. 1912-13, Hollinger Gold Mines, Ltd.

Present position: 1913 to date, Asst. Supt., Virden Brass Co., Cleveland, Ohio.

Robert Geiser Davies, Wonder, Nev.

Proposed by E. E. Carpenter, E. S. Cunningham, E. G. Spillsbury.

Born, 1884, Emmetsbury, Iowa. 1905, B. A., Univ. of Iowa. 1911, B. S., University of Cal. 1911-12, Grad. Student in Geology and Petrography, Univ. of Cal. 1911-12, Asst., Dept. of Geology, Univ. of Cal. 1912, Aid, U. S. Geological Survey.

Present position: 1913 to date, Engineer, Nevada Wonder Min. Co.

Emilio Diaz, Llalagua, Bolivia, S. A.

Proposed by Durward Copeland, H. A. Buehler, G. H. Cox.

Born, 1883, Santiago, Chile. 1898-1901, Chilean Government Military Academy. 1901-05, Lt. of Artillery, Chilean Army. 1906-10, Student in Min. Eng. at Missouri School of Mines, Rolla, Mo.; B. S. 1910-11, Engineer, Braden Copper Co., Rancagua, Chile. In charge of developing and exploiting work of the Fortuna Mines of Braden Copper Co. 1911-14, Mine Supt., Chief Engineer, and General Manager, Compania Estanifera de Llalagua.

Present position: General Manager, Compania Estanifera de Llalagua, Llalagua, Bolivia, S. A.

Charles Franklin Dike, Jr., Cobalt, Ont., Canada.

Proposed by Henry C. Carr, Arthur A. Cole, Kirby Thomas.

Born, 1876, Crystal Lake, Ill. 1901-05, Civil Engineering, Sheffield Scientific School, Yale Univ.; Ph.B. Supplemented by two years in chemistry, metallurgical work, mineralogy, geology, etc. 1905-07, Stratton's Independence, Ltd., Engineer. 1907-08, Barnes King Development Co., Engineer. 1908, Examination work in Montana and Old Mexico. 1909, Examination work, Joplin, Mo. 1909-10, Supt. and Engineer, Stratton Cripple Creek Dev. Co. 1910-12, Mgr., Crown Chartered G. M. Co., Porcupine.

Present position: 1913 to date, Manager, Cochrane Mines of Cobalt, Ont., Canada.

T. H. Powers Farr, Jr., New York, N. Y.

Proposed by Bradley Stoughton (two additional signatures required).

Born, 1885, Orange, N. J. 1903-07, A. B., Princeton Univ. 1907-09, School of Mines, Columbia. 1909, American Smelters Securities Co., at Velardena, Mexico. 1909-1910, same company at Metehuala, San Luis Potosi, as engineer.

Present position: 1911 to date, Examination and development work for private individuals in Ecuador and Southern Colombia, S. A.

Charles Reinhard Fettke, Pittsburg, Pa.

Proposed by C. T. Griswold, Fred Crabtree, L. B. Smith.

Born, 1888, San Francisco, Cal. 1906-07, Washington State College, Pullman, Wash. 1907-10, College of Mines, Univ. of Washington, Seattle, Wash.; B. S. in Min. Eng. 1910-13, Graduate Student, Columbia Univ., New York; A. M. 1914, Ph.D. Summers of 1909-10-11, Field Asst. Washington Geological Survey, Seattle, Wash. 1911-13, Asst. in Geology, Columbia Univ., N. Y. Summer 1912, Instructor in Geology, Columbia Univ. Summer 1913, Geologic Aid, U. S. Geological Survey.

Present position: Instructor in Geology, Carnegie Inst. of Tech.

Fusajiro Fuketa, Tajima, Japan.

Proposed by T. Wada, Shinji Harada, Takeshi Kawamura.

Born, 1868, Omi, Japan. 1890, Graduate Tokyo Mining School. 1890-97, Hibara and Kuratani Mining Co., as Asst. engineer. 1897 to date, Ikuno mine's smelter of Mitsubishi Co., as Metallurgist.

Present position: Supt. in Ikuno smelting works.

Alexander Grosberg, Llallagua, Bolivia, S. A.

Proposed by Durward Copeland, H. A. Buehler, G. H. Cox.

Born, 1889, St. Louis, Mo. 1907, Grad. Yeatman High School, St. Louis, Mo. 1912, Grad. Missouri School of Mines and Metallurgy; B. S. 1910, In charge of Custom Assay Office of American Mine Engineering Co., Joplin, Mo. 1911-12, Student Asst. in Chemistry, Missouri School of Mines and Metallurgy. 1912, Chemist, American Steel Foundries, East St. Louis, Ill. 1912, Experimental work in Flue Dust, Old Dominion Copper Smelting Co., Globe, Ariz. 1913, Sampling Dept., Braden Copper Co., Rancagua, Chile, S. A.

Present position: 1913 to date, Supt. of Mill, Cia. Estanifera Llallagua, Bolivia, S. A.

Paul Hammond, London, E. C., England.

Proposed by Hugh Vivian, Herbert K. Scott, E. Coppee Thurston.

Born, 1884, Jandiah, Brazil. Educated at an English Public School and afterward graduated at the Royal School of Mines at Freiberg, in Saxony, Germany (1908). Worked as pupil in various mining, metallurgical and engineering enterprises, including Fraser & Chalmers Workshops at Erith, England, and the Mining and Smelting works in Saxony and Bohemia. 1909, was engaged in prospecting in Brazil in the States of Sao Paulo, Minas, Parana, Santa Catharina and Rio Grande do Sul. 1910, Asst. General Mgr. to the Uruguay Cons. Gold Mines, Ltd. 1912, Examined and reported on the Geology of the Marstin District, Bahia, Brazil.

Present position: Consulting work in gold, copper and oil mining propositions.

Herbert John Heffner, Centralia, Pa.

Proposed by Thomas M. Righter, J. M. Humphrey, Charles Enzian.

Born, 1876, Ashland, Pa. 1893, Graduate of Centralia High School, Graduate of International Correspondence Schools of Scranton, Pa., Mechanical Course. 1898, Started on Engineer corps of Lehigh Valley Coal Co. at Centralia, Pa., as back-sight and was gradually promoted to the different positions on the corps and made Div. Engineer in 1910 and was promoted to Div. Supt. in 1912.

Present position: Division Supt., Lehigh Valley Coal Co., Centralia, Pa.

Charles S. Heislar, Bisbee, Ariz.

Proposed by Charles A. Mitke, Roger T. Pelton, Alexander V. Dye.

Born, 1886, Hutchinson, Kan. Urbana Illinois High School; B.S. 1910, National Malleable Castings Co., Chicago, Ill. 1911, Western Electric Co., Chicago, Ill. 1912, Peoples Gas Light & Coke Co., Chicago, Ill. 1913, Copper Queen Cons. Mining Co.

Present position: Min. and Mechanical Engr., Copper Queen Cons. Min. Co.

Milton White Heller, Denver, Colo.

Proposed by Russell B. Paul, E. W. Leith, Robert Hursh.

Born, 1889, New York City. 1896-1902, Grammar Schools, N. Y. 1902-05, Townsend Harris Hall High School, N. Y. C. 1905-09, College of the City of N. Y.; B. S. 1909-12, Columbia Univ. School of Mines; E. M. 1912-13, three months underground work, Federal M. & S. Co., Mullan, Idaho. 1912-13, Crushing and concentrating depts., Snowstorm Copper Co., Larson, Idaho. 1913, Three months, Chemist, Ricketts & Banks, N. Y. C.; Mill design, Piedmont Manganese Corps, Va.; prospecting and diamond drill work, New Jersey Zinc Co.; three months, Insp. of Masonry, Aqueduct Dept., N. Y. C. Board of Water Supply.

Present position: Mining Engineer, Empire Zinc Co.

Frank H. Hemelright, Scranton, Pa.

Proposed by Irving A. Stearns, R. V. Norris, Douglas Bunting.

Born, 1870, Beaumont, Pa. Public Schools, Wood's Business College, Scranton. 1892-98, Foreman, Edgerton Colliery. 1898-1903, Division Supt., Edgerton Northwest, Sterrick Creek, and Lackawanna Collieries of Temple Iron Co.

Present position: Gen'l Supt. of above and Babylon, Harry E., Forty Fort and Mt. Lookout Collieries.

Stanley C. Herold, Philadelphia, Pa.

Proposed by G. H. Clevenger, H. Foster Bain, H. W. Young.

Born, 1883, San José, Cal. Grad. of Min. Dept., Stanford Univ., Cal. Asst. Surveyor New Idria Quicksilver Mines, New Idria, Cal. Asst. Engineer, Mont. Tonopah Min. Co., Tonopah, Nev. 1908-09, Engineer and Geologist, MacNamara Min. Co., Tonopah, Nev. 1910-11, Construction Engineer, Union Construction Co. 1912, Seward Peninsula, Alaska.

Present position: Supt., Caribbean Petroleum Co., Maracaibo, Venezuela.

Chieh Ho, So, Bethlehem, Pa.

Proposed by Joseph W. Richards, Howard Eckfeldt, Benjamin L. Miller.

Born, 1890, Canton, China. 1903-07, Canton Christian College, South China. 1907-09, Tongshan Engineering and Mining College, North China. 1910-13, Colorado School of Mines, Golden, Colo., E. M. 1907-09, Underground work in the Kaiping Coal Mines. Summer of 1911, Practice of field geology and prospecting in the Estes Park region, Colo. Summer of 1912, Field work in connection with the State Geological Survey of Colo. Spring 1913, Inspection trip to important mining camps in the States of Colorado, Utah, Montana, for advanced work in geology, mining, metallurgy, and engineering.

Present position: Post-graduate student in Lehigh Univ.

Scovill E. Hollister, Llallagua, Bolivia, S. A.

Proposed by Durward Copeland, H. A. Buehler, G. H. Cox.

Born, 1892, Arlington, Kan. 1908, Grad. Princeton, Mo., High School. 1913-Grad. Missouri School of Mines and Metallurgy, Rolla, Mo.; B. S. 1912, Summer, Acting City Engineer at Marshall, Mo. 1911-12, Student Asst. in Chemistry at Missouri School of Mines. 1912-13, Student Asst. in Physics and Electricity, Missouri School of Mines.

Present position: Chief Chemist, Cia. Estanifera, Llallagua, Bolivia, S. A.

Robert Lang, Garnsey, Ala.

Proposed by H. S. Geisner, B. F. Roden, Erskine Ramsay.

Born, 1871, Scotland. 1881, Common School in Scotland. 1882, Night school, New Mexico. Home study constantly with my father for a number of years. Took a course in the Correspondence School of Mines at Scranton, Pa. I have for a number of years made the science of coal min. a part of my regular study. 1883, San Pedro Coal & Coke Co. at Carthage, N. M. 1886 or '87, Galloway Coal Co. at Carbon Hill, Ala., as hoisting engineer. 1890, went into business with father and brother-in-law. Opened Chickasaw mine, near Carbon Hill, Ala. Operated this property for a num-

ber of years, then sold it to the Galloway Coal Co. of Memphis, Tenn. 1899, With the Ala. Cons. Coal & Iron Co. as Master Mechanic and Asst. Supt. for a little more than ten years. 1910-11, Became a stockholder in the Birmingham Fuel Co. at Townsley, Ala., and the Caladone Coal Co. of Jasper, Ala. Company sold the Birmingham Fuel Co. to Morris Adler & Bros. of Birmingham. Sold the Caladone Co. to John H. Bankhead and brother William of Jasper, Ala.

Present position: 1912 to date, Supt. Bibb County Div., Galloway Coal Co., located at Garnsey, Ala.

Howard S. Lee, Rye Valley, Ore.

Proposed by A. M. Swartley, H. M. Parks, E. B. Kirby, S. J. Jennings.

Born, 1880, Golden, Colo. 1899-1903, four years Leland Stanford Junior Univ. 1906-07, Asst. Engineer, Vindicator Cons. Gold Mining Co., Independence, Colo. 1907-09, Engineering Dept., Camp Bird, Ltd., Ouray, Colo. 1909-14, Exploration Dept., U. S. Smelting, Refining & Min. Co.

Present position: Manager, Rainbow Mine, Rye Valley, Ore.

W. Frank Lewis, Santa Rita, N. M.

Proposed by A. M. Bateman, Augustus Locke, John M. Sully.

Born, 1886, Sand Lake, Mich. 1899-01, Ironwood, Mich. 1901-02, Business College, Big Rapids, Mich. 1909-11, Michigan College of Mines; B. S., E. M. 1902-03, Cleveland Cliffs Iron Co. 1906-08, Ojibway Min. Co. 1911-12, Shannon Copper Co. 1913, Cleveland Cliffs Iron Co.

Present position: Engineer, Chino Copper Co.

Augustus MacDonald, Guanajuato, Mexico.

Proposed by Henry P. Smith, Joseph MacDonald, Bernard MacDonald.

Born, 1884, Silver City, N. M. 1903, Grad. from Hill Military Academy, Portland, Ore. 1905-07, Stanford Univ. Took up the regular work of the freshman and sophomore years in geology and mining. 1903, Assayer, Cornucopia Mines Co., Cornucopia. 1904, Asst. Assayer and Assayer, Alaska Treadwell Min. Co., Treadwell, Alaska. 1904, Assayer, Sheep Creek Min & Mill Co., Sheep Creek, Alaska. 1904-5, Mine Foreman, Carmen Gold Min. Co., Guanajuato, Mexico. 1905, Cyanide Solution man. Gto. Cons. Min. & Mill Co., Guanajuato, Mex. 1907-09, Assayer, Gto. Cons. Min. & Mill Co., Gto., Mex.

Present position: 1909 to date, Cyanide Supt., Guanajuato Reduction & Mines Co.

Frank B. Miller, Blair, Nev.

Proposed by Lyon Smith, S. J. Kidder, W. D. Bursham.

Born, 1884, Bellevue, Pa. 1903-05, W. & J. Academy, Washington, Pa. 1905-06, W. & J. College, Washington, Pa. 1906-09, Penn. State College; B. S. 1909, Kerr Lake Min. Co., Cobalt, Can. 1909-10, Mountain Copper Co., Iron Mountain, Cal. 1910, Balaklala Copper Co., Kimberly, Cal., timberman, diamond driller, engineer's helper, and night timekeeper.

Present position: Mining Engineer, Pittsburg Silver Peak Gold Min. Co., Blair, Nev.

John R. Mitchell, Chicago, Ill.

Proposed by G. M. Davidson, C. W. Gennet, Jr., William Hopkins.

Born, 1873, Lafayette, Ind. 1889-91, Purdue Univ., Lafayette, Ind. 1893-98, Special apprentice, Chicago & North Western Ry. 1898-99, Inspector of iron and steel at various works in U. S. for C. & N. W. Ry. 1899-1902, Various positions with Chicago & North Western and Atchison, Topeka, and Santa Fé Ry. 1902, Inspecting iron and steel at various works in U. S. for Chicago & North Western Ry.

Present position: 1902 to date, Metallurgical Engineer, W. H. Miner.

Douglas Muir, San Antonio, Texas.

Proposed by Henry P. Smith, Robert L. Brown, Bernard MacDonald.

Born, 1882, San Antonio, Texas. 1900-02, Williams College, Williamstown, Mass. 1902-05, Colo. School of Mines, Golden, Colo.; E. M. 1905-06, with F. J. Hobson, general engineering and metallurgical work. 1906, In charge construction and operation Ave De Gracia mill and cyanide plant, Dolores, Gto. 1907, Supt. Cabrestante Mine, Gto., for Dwight Furnace Co. 1907, Supt. Cinco de Mayo mines, Descubridora, Dgo., for E. Harms. 1908, Shift Boss, mill and cyanide plant, Indo Gold Mine Co., Indo, Dgo.

Present position: Asst. Genl. Mgr., Guanajuato Reduction & Mines Co.

Roy L. Reynolds, Trimountain, Mich.

Proposed by H. T. Mercer, F. W. Denton, W. E. Hopper.

Born, 1883, Cheshire, Mass. 1900, Graduated Cheshire High School. 1906-08, Student in engineering dept. at Univ. of Vermont. 1908-10, Student at Mich. College of Mines. 1911, Student at Mich. College of Mines; B. S. and E. M. 1900-06, Working around lime plant and quarry in no official capacity. 1910-11, Working underground for six months at Calumet & Hecla mines, Calumet, Mich. 1910-11, Six months underground at the Boston American Iron Mine. 1912, Engineering at Champion Mines, under H. T. Mercer. 1913, Charge of Engineering at Trimountain Mine, under H. T. Mercer.

Present position: Underground Supt. at Trimountain Mine.

Chris. A. Rodegerdts, San Francisco, Cal.

Proposed by F. Lynwood Garrison, Robert E. Cranston, H. Foster Bain.

Born, 1886, Sacramento, Cal. 1893-1906, Public Schools of Sacramento, Cal. 1906-10, Univ. of Cal., B. S. 1907-09, Assayer, Draftsman and Clean-up Surveyor for Ashburton Min. Co. and Marysville Gold Dredging Co., Marysville and Folsom, Cal. 1909, Practical min., Empire Mine, Grass Valley Cal. 1910, Practical min. and mill work, Goldfield Cons., Goldfield, Nev. 1910-11, Asst. Experimental Engineer, Arthur Mill of Utah Copper Co., Garfield, Utah. 1911-14, Short examination trips as Asst. to F. Lynwood Garrison, E. M.

Present position: 1913 to date, Asst. Civil Engineer, Building Supt. Dept., Division of Works, Panama Pacific International Exposition:

Ignace Schilowsky, Riasan, Russia.

Proposed by W. T. Burns, E. S. Bardwell, E. E. Brownson.

Born 1882, Riasan, Russia. High School in Riasan, Russia. Univ. of Moscow, Russia. Univ. of Göttingen, Germany. Royal Institute of Technology. Karlsruhe, Germany. 1910, E. M., Royal Institute of Technology in Aachen, Germany, 1911, Actien Gesellschaft Zu Stolberg in Westphalen, Chemist.

Present position: 1913 to date, Anaconda Copper Min. Co., B. & M. Reduction Dept., Investigator.

Peter B. Scotland, Morenci, Ariz.

Proposed by Norman Carmichael, F. N. Flynn, R. B. Earling.

Born, 1846, Scotland. 1894-97, Anderson's College and Technical College, Glasgow. 1897-99, Mining College, Coatbridge. 1899-1904, Royal School of Mines, London. Ariz. Copper Co., Ltd. 1902-05, Asst. Mine Supt. 1905-1913, Mine Supt., Metcalf and Caronada Mines.

Present position: General Supt. of Mines, Ariz. Copper Co., Ltd.

Tokutaro Segawa, Fukui-Ken, Japan.

Proposed by T. Wada, Shinji Harada, T. Kawamura.

Born, 1872, Morioka, Japan. 1898, Grad. Min. and Metallurgical Dept., Tokyo Imperial Univ., Japan. 1898, Mitsubishi Co., and served as a mining engineer at the mines Ikuno, Yoshi, Oka, and Omodani.

Present position: Mining Engineer, Manager of the Omodani Copper Mine.

Luciano Selmi, Ashland, Wis.

Proposed by J. E. Johnson, Jr., William Wilkins, William E. McRandle.

Born, 1879, Modena, Italy. 1896, Graduate, Royal Lyceum of Modena. 1897-1901, Graduate, Royal Univ. of Modena; D. S. 1902-03, Post Graduate work in Organic Chemistry at the Royal Polytechnic of Milano, Italy. 1903, Transitman Shawmut Min. Co., St. Marys, Pa. 1904, Charge of Laboratory for Bloms Mfg. Co., N. Y. 1905, Engaged in making drawings and plans for building contractors in Cleveland, O. 1906-07, Chemist with Grasselli Chemical Co., East Chicago, Ind., works.

Present position: Chief Chemist for Lake Superior Iron & Chemical Co., Ashland, Wis.

A. Lester Sharp, Ontario, Canada.

Proposed by Alfred W. G. Wilson, Howells Frichette, L. H. Cole.

Born, 1882, Summerside, P. E. I. 1900-02, Prince of Wales College, Charlottetown, P. E. I. 1902-07, McGill Univ., Montreal; B. S. 1905-06, Drafting on Construction, Dominion Iron & Steel Co., Sydney, N. S. 1907, Construction, Mond Nickel Co., Victoria Mines, Ont.

Present position: 1908 to date, Supt. of Garson Mine, Mond Nickel Co.

Kanao Shinjio, Ibarakiken, Japan.

Proposed by T. Wada, Shinji Harada, T. Kawamura.

Born, 1878, Iwakunimachi, Yamaguchiken. 1906, Grad. Min. and Metallurgical Dept. Tokyo Imperial Univ., Japan. 1906, Mitsubishi Co., and served as a Supt. of min. dept. at the Sado Mine and as chief Engineer at the Takatori Mine.

Present position: Chief Mining Engineer, Mitsubishi Takatori Tungsten Mine, Ibarakiken.

Warren D. Thompson, Rancagua, Chile, S. A.

Proposed by Pope Yeatman, Edwin S. Berry, Robert Marsh, Jr.

Born, 1882, St. Louis, Mo. 1899, Pierce Grammar School, Brookline, Mass. 1903 Brookline High School, Brookline, Mass. 1907, Lawrence Scientific, Harvard Univ., B. S. Mining. 1907, Dairy Farm Mine, Placer County, Cal., underground. 1907, Golinsky Mine, Kennett, Cal., underground. 1907, Mammoth Smelter, Kennett, Cal., furnace crew, Sampling Dept. 1908, Cardinal Min. Co., Poland, Ariz., sampling and assaying. 1909, Tiger Gold Co., Harrington, Ariz., Engineering. 1909, Robins Conveying Belt Co., N. Y., Engineering. 1910, Braden Copper Co., N. Y., Engineering. 1911, Examination Trip to Alaska, Yukon Gold Co., Engineering. 1912, C. R. R. of N. J., N. Y., Engineering.

Present position: 1912 to date, Braden Copper Co., Rancagua, Chile, S. A., Chief Engineer of Mine.

Edwin Bryant Thornhill, Cobalt, Ont., Canada.

Proposed by Tom R. Jones, Arthur A. Cole, Albert W. Johnston.

Born, 1882, Hillsboro, Mo. 1908, Graduate Missouri School of Mines; B. S. 1905-06, Rodman, Transmittan and Assistant Engineer on Division for Missouri Pac. R. R. 1908-10, Chemist and Supt. for North American Lead Co. 1910-13, Member of firm of engineers engaged in general engineering at Salmon, Idaho.

Present position: Supt., High Grade Plant, Buffalo Mines, Cobalt, Ont., Canada.

Guy M. Vail, Portland, Ore.

Proposed by C. L. Colburn, Victor C. Alderson, J. M. McClave.

Born, 1880, Georgetown, Colo. 1888-95, Public Schools, Denver, Colo. 1895-97, Preparatory Course, Denver, Colo. 1897-99, Colo. School of Mines. 1900-02, Assay office in Denver. 1902-05, Assayer and Chemist, American Smelting & Refining Co., Globe Plant, Denver. 1905-07, Chemist, General Mill Foreman, General Surface Foreman, Asst., Supt., Braden Copper Co., Rancagua, Chile. 1908-09, Supt., Gold Creek M. & M. Co., Salem, Ore. 1910-12, General Manager, Mt. Shasta Min. Co., Redding, Cal.

Present position: General engineering office, Portland, Ore. Consulting Engineer for Kohimer Min., Mill. & Pow. Co., Ely, Nev.

M. M. Valerius, Tulsa, Okla.

Proposed by V. H. McNutt, G. H. Cox, H. A. Wheeler,

Born, 1872, Sigauney, Iowa. 1890-94, Drake Univ., Des Moines, Ia. 1913, Special Geology, Missouri School of Mines, Rolla, Mo. 1904-08, Field geology, oil and gas, Wyo., Mont. and Kansas. 1909-10, Field geology, coal, ore.

Present position: Member firm of Valerius & McNutt, Geologists, Tulsa, Okla.

Roy Wetherod, Ainsworth, B. C., Canada.

Proposed by R. G. Holmes, L. K. Armstrong, Richard S. McCaffery.

Born, 1883, Mo. 1905, Grad. Min. Engineer, Univ. of Idaho. 1905, Hecla Min. Co., Idaho. 1906-07, Guanajuato Gold Mines Co., Mexico. 1907-08, Mexico Mines of El Oro, Mexico. 1909, With smelter of H. C. Harrison, Mexico.

Present position: 1910 to date, Mine and Mill Supt., Cons. Min. & Smelting Co.

Francis Winslow, Telluride, Colo.

Proposed by Arthur Winslow, Charles A. Chase, J. F. McClelland.

Born, 1899, Jamestown, R. I. 1903-07, Hartford, Conn., High School. 1907-10, Sheffield Scientific School; Ph. B. 1910-12, Sheffield Scientific School; E. M. 1909, Rodman, Liberty Bell Gold Min. Co. 1910, Millman, Liberty Bell Gold Min. Co. 1911-12, General mine and mill experience, engineering, and assaying, Dome Mines Co., Ltd., South Porcupine, Ont., Canada.

Present position: Asst. Engineer, Liberty Bell Gold Mining Co., Telluride, Colo.

Associates

James A. Caselton, St. Louis, Mo.

Proposed by Herman Garlich, Arthur P. Watt, Philip N. Moore.
Born, 1885, Batchtown, Ill. 1893-1905, County Common Schools.

Present position: 1906 to date, St. Louis Smelting & Refining Co.

Wilbur Lucius Cross, Jr., New Haven, Conn.

Proposed by J. F. McClelland, Joseph W. Roe, L. W. Bahney.

Born, 1892, Willimantic, Conn. 1912, Degree of Ph. B. from the Sheffield Scientific School of Yale Univ. Grammar and High School education at New Haven before entering the Univ.

Present position: Graduate Student in the Dept. of Min., Sheffield Scientific School, Yale Univ.

David M. Goodrich, New York, N. Y.

Proposed by C. M. Weld, H. P. Henderson, Robert P. Bowles.

Born, 1876, Akron, Ohio. 1898, A. B., Harvard.

Present position: Director, Pozo Gilpin Co.

Albert John Meier, St. Louis, Mo.

Proposed by Herman Garlich, Arthur Thacher, Philip N. Moore.

Born, 1875, St. Louis, Mo. 1889-93, Manual Training School, St. Louis, Mo. 1911, General Mgr. and 2nd Vice-President, St. Louis Smelting & Refining Co., operating lead mines at St. Francois, Mo., and a lead smelter at Collinsville, Ill., and properties at other points. Now operating the Mine La Motte at Mine La Motte, Mo.

Present position: General Mgr., St. Louis Smelting & Refining Co.

James B. Wilson, McKeesport, Pa.

Proposed by Taylor, Allderice, P. C. Patterson, W. A. Cornelius.

Born, 1874, Pa. Common school. 1890-1900, Chemical laboratories of the Edgar Thomson Steel Works and blast furnaces of the Carnegie Steel Co., Braddock, Pa., and the Monongahela blast furnaces and steel works of the National Tube Co., McKeesport, Pa. 1900-02, Supt., Monongahela blast furnaces. 1902-07, Supt., Monongahela blast furnaces and steel works, of the National Tube Co., National Works, McKeesport, Pa., and the Republic Iron & Steel Works, Pittsburg, Pa.

Present position: Supt., Lower Departments, of the National Tube Co., National Works, McKeesport, Pa.

CHANGES OF ADDRESSES OF MEMBERS

The following changes of address of members have been received at the Secretary's office during the period Mar. 1 to 15, 1914. This list, together with the lists published in *Bulletin* Nos. 76 to 87, and the foregoing list of new members, therefore, supplements the annual list of members corrected to Mar. 1, 1913, and brings it up to the date of Mar. 15, 1914.

AGNEW, WILLIAM C.	218 N. 15 Ave. E., Duluth, Minn.
ARKELL, HARRY J.	79 St. James Ave., Beckenham, Kent, Eng.
ATKINSON, LOUIS W.	1503 Rhode Island Ave., Washington, D. C.
BOKER, H. C.	Marienstrasse 11, Remscheid, Germany.
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1894	*Sperry, Edwin S.	
1904	*Woodbury, Frederick Elwell.	January 21, 1914

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Sound Ingots

BY SIR ROBERT HADFIELD,* F. R. S., LONDON, ENGLAND

(New York Meeting, February, 1914)

LAST year this Institute was good enough to accept some remarks by the writer regarding sound steel, entitled Plant for Hadfield Method of Producing Sound Steel Ingots, being a continuation of a research in which for some time the writer has been engaged, and full particulars of which were submitted in papers entitled A New Method of Revealing Segregation in Steel Ingots, and Method of Producing Sound Ingots, read before the Iron and Steel Institute in October, 1912. These papers gave rise to a very interesting discussion, both in England and America.

This question is one of vital importance, as unless sound steel in the form of ingots is first obtained, sound steel in the finished forms of rail billets, rails, bars, sheets, and other forms cannot be expected. The working stresses demanded by modern conditions are so great, each year they probably approach nearer to the limit of safety, that without doubt those who produce steel will be compelled to pay the attention which this subject deserves. Moreover, the problem is not an insuperable one, as shown by the writer in the papers above referred to.

In view of the information which has already been presented in these papers, it is not now necessary to go into details of the system advocated by the writer, except to repeat that the ingots and steel now referred to were produced by employing in the first place sound fluid steel, free from blowholes, this being poured into ordinary ingot molds, provided with the necessary feeding heads, the insulating slag medium, also charcoal and air blast or other suitable form of applying heat to the head portion of the ingot. The upper or head portion of the ingot is kept fluid by the intense heat generated by the air blast and charcoal, so that such fluid steel passes into the body of the ingot below the head, thus feeding and avoiding the shrinkage or piping which would otherwise occur. The result is the production of a sound steel ingot, free from blowholes, segregation and piping, and in which the waste portion, usually termed the discard, is but little over 7 or 8 per cent.

Billets produced from such ingots have shown a salable product of about 91 per cent., including the oxidation losses in heating and rolling. Plate I shows the details of the products obtained from such an ingot. While these results were obtained from a comparatively small ingot, 11 in.

* Honorary Member.



FIG. 1.—11-in. Ingot, 4 ft. 4 in. long, weighing 1,680 lb.



FIG. 2.—Billet from top portion of Ingot.



FIG. 3.—Billet from bottom portion of Ingot.



FIG. 4.—Section at *A* of Fig. 2. Sound metal.



FIG. 5.—Section at *B* of Fig. 2, 1 in. from *A*. Last trace of piping.

square, weighing 1,680 lb., the same results have been obtained from 14, 15, 18, and 20 in. ingots.

G. Charpy of the Cie. des Forges et Acieries de Chatillon-Commentry et Neuves-Maisons, Montluçon (Allier), also made an ingot weighing 25 tons under this system, and reported to the writer the following results with regard to the system as applied to larger ingots.

M. Charpy stated that the Hadfield method of feeding the upper portion of the ingot in the special manner described in the papers mentioned above, namely, sand head, air blast, charcoal, and insulating layer of slag, appeared to him to constitute a particularly simple and practical solution of the problem met with in steel manufacture, and to overcome the difficulties met with as regards piping; also to reduce segregation and avoid the large percentage of waste material.

In Plate II, Fig. 1 represents a photograph taken by M. Charpy of the upper part of an ingot weighing 25 tons. This ingot has been treated by the writer's method, its composition being: Carbon, 0.40; sulphur, 0.02; phosphorus, 0.04; manganese, 0.45 per cent. The material also contained a small percentage of nickel.

Fig. 1 shows the satisfactory nature of the method. The portion of the ingot shown in the photograph represents about one-fourth of its total length. M. Charpy found that in order to eliminate all faults and sponginess in the ingot in question, it was only necessary to cut off about 12 to 12½ in. from the upper part; in other words, about one-twentieth of the ingot, as against one-third which is the proportion of discard ordinarily required. The waste and segregated material in this ingot only amounted to about 5 per cent. of the total weight.

Moreover, the analyses taken of the material at different parts of the ingot show this is free from segregation.

Fig. 2 shows the parts from which the analyses given in the table were taken.

Drillings were taken on the center line at the different parts shown, commencing at the top, marked A, also at the other parts as lettered.

Portion Drilled	S Per Cent.	P Per Cent.	Portion Drilled	S Per Cent.	P Per Cent.
A.....	0.016	0.043	K.....	0.012	0.044
B.....	0.018	0.041	M.....	0.018	0.039
C.....	0.028	0.043	N.....	0.017	0.039
D.....	0.024	0.042	O.....	0.026	0.044
E.....	0.021	0.039	P.....	0.028	0.045
H.....	0.020	0.043	R.....	0.015	0.038
I.....	0.020	0.039	X.....	0.015	0.038

Fig. 3 shows the dimensions of the ingot.

With reference to the question of soundness of material, it may be interesting to point out that in the smaller ingot shown in Plate I, Fig. 1, from which the billets were obtained, Figs. 2 and 3, even including the sand head portion (termed head or discard in Plate I), the total head or discard was only 2 ft. 5 in. in length. By cutting off 1 in. more, Fig. 4 shows the polished section from the top portion of this billet at the part marked *A* in Fig. 2; then comes the length of 1 in. removed; above this is the head or discard mentioned, 2 ft. 5 in. in length.

Fig. 5 represents the polished section from the top portion of the billet at the part marked *B* in Fig. 2. In other words, Fig. 5 shows the last traces of piping near the head, at the part marked *B* in Fig. 2, while Fig. 4, 1 in. further down, shows the complete removal of this piping, represented by the polished section from the top portion of the billet at the part marked *A* in Fig. 2. That is to say, the material represented in Fig. 4 and that below this represents sound material.

Fig. 5 also represents the head or discard of this ingot. The ingot as cast weighed 1,680 lb.; the discard removed weighed 123 lb., or 7.3 per cent. of the total weight of the ingot. The total weight of sound billet was 1,513 lb. or 90 per cent.

In a similar manner, from another ingot there was obtained a sound rail having a total length, wholly free from pipe, of 62 ft. 7 in., with a discard of only 18 in. of rail, and in addition to this, the ingot head itself, representing 7 to 8 per cent. of the weight of the ingot.

In order to further illustrate this method, Plate III represents four ingots, *A* and *C* made by the writer's system, *B* and *D* ingots made in the ordinary way. Ingot *B* was cast from slightly rising steel, and ingot *D* from piping steel but not fed. Ingots *A* and *B*, also *C* and *D*, were cast from the same heats respectively. These ingots are also shown in vertical position in Plate IV.

Another illustration is shown in Plates V and VI of ingots made in the ordinary way. These represent 18-in. ingots, weighing about $2\frac{1}{4}$ tons each, cast with the small end up, *A* being rising or unsound material, and *B* piped material but not fed.

In comparison are shown Plates VII and VIII, which also represent the same sized ingots, namely 18 in., made by the writer's system, weighing about $2\frac{1}{4}$ tons each. These are interesting because the ingots were cast with the small end up, as in ordinary practice. Plate VII gives an excellent view of the cavity produced by the sound steel in these ingots as it settles down into the body of the ingot proper, that is below the feeding head. As will be seen, by a merely superficial examination of such an ingot, occupying but a few seconds, it can be determined whether the steel in the ingot itself is sound or not. If the cavity is there, the material below in the ingot proper will be perfectly sound and free from honeycombs, blowholes, segregation, or piping.



A and C, Hadfield system. B and D, ordinary method.

PLATE III.—15-in. Ingots, weighing about 2 tons each.

It will be admitted by any impartial observer that it is, on the other hand, quite impossible, by looking at either of the ingots shown in Plate V, made in the ordinary manner, that is without the head or feeding arrangement, to determine whether these are sound or unsound, or the nature of the unsoundness or piping present in them, that is below the top of the ingot. In other words, the ingots would have to be sliced



PLATE IV.—ANOTHER VIEW OF THE INGOTS SHOWN IN PLATE III.

up by machining, and thus spoiled for actual work, before it could be decided whether they would give perfectly sound material, whereas in the ingots shown in Plate VII, made under the writer's system, machining or other observation carried out by mechanical methods is entirely unnecessary, and at least 88 to 90 per cent. of sound usable and salable material is obtained. This, too, can be accomplished just as readily and easily with 10,000 as with one ingot.

any government inspector the writer has ever met, yet in a rail, upon which human life so largely depends, it seems to be taken as a matter of course that such a product may safely pass into service.

As regards steel of piping nature, but cast without a feeding head, such as shown by *B* in Plate V, this is probably the more dangerous of the two types shown in this plate, as in the case of a warm heat the piping will descend to a greater depth. While a certain portion of this may be got rid of in the discard, this often amounting to a large percentage, yet this means great waste. Moreover, and this is still more important to be borne in mind by the user of the rail, there are cases showing that below the portion where the pipe has been supposed to terminate, this sometimes breaks out again and is not detected. In other words, a discard may be taken and show sound material, yet below this it is easily possible to have further dangerous segregation and piping.

As regards the length of time required for ingots made under the system now described to cool down before they can be dealt with, it is estimated that probably not more than about 15 min. would be necessary.

To further differentiate between the various types of ingots as now produced and as made by the writer's system, the reader is referred to Plate IX, which gives this in a graphic manner.

Fig. 1 represents badly rising steel, which is full of blowholes almost entirely throughout the mass; the steel rises and shows practically no piping. Although in rolling this steel the blowholes are apparently closed up, without doubt by a careful examination of its microstructure it would be found that the material can never be as strong or as dense as steel made sound in the first instance. The product is, moreover, liable to segregation in the upper portion. A large discard is necessary, in some cases as much as 20 per cent. or more.

Fig. 2 represents steel which neither rises nor settles. In this steel there are fewer blowholes, but the steel is still unsound, with a tendency to pipe. This steel contains considerable unsoundness, and owing to the tendency to pipe, troubles are liable to occur with segregation and piping. Probably at least 15 to 20 per cent. discard is necessary.

Fig. 3 represents settling steel which is not fed in the upper portion, as in the case of those ingots made by the writer's system. This pipe sometimes runs half the length of the ingot. Moreover, such material has sometimes a tendency to appear sound, then below this to break out again into piping. While this steel is free from blowholes, material of uncertain nature is obtained, owing to its badly piped condition. It is probably this kind of steel which gives the dangerous rails below those made from what are known as the upper or *A* and *B* portions of the ingot. In other words, it is quite possible piped or unsound *C* rails may be obtained from such ingots.

Fig. 4 represents an ingot made under the writer's system. The steel

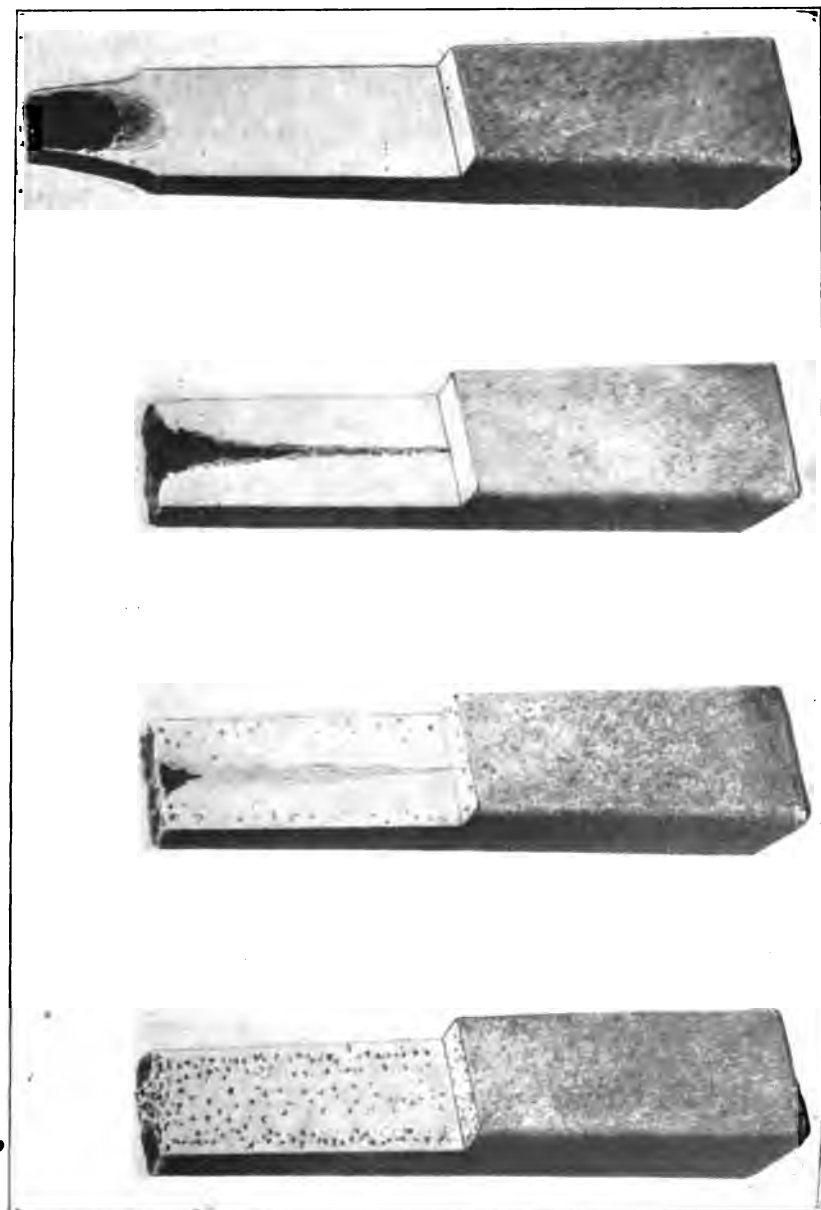


Fig. 4.

Fig. 3.

Fig. 2.

Fig. 1.

PLATE IX.

used in the first place is perfectly sound and free from blowholes. The feeding arrangement enables from 88 to 90 per cent. of the total weight of ingot to be safely used. In some cases, no less than 93 per cent. of sound billets have been obtained from ingots made in this manner; that is, 93 per cent. of the material showed neither blowholes, piping, segregation, nor other defects.

With reference to the cavities or hollow portions in the heads of the ingots made by the writer's system, in view of the extraordinarily large nature of these cavities, the writer decided to make the following experiment with a view to determine the exact value of the settling of the steel from the head above the ingot into the ingot itself. He believes that such a method of testing ingots has not before been carried out. It will be understood this has only been made for experimental purposes, because by an examination from the top of the ingot, occupying only a few seconds, it can be easily determined whether the ingots when produced in course of manufacture, whether in small or large quantities, possess the necessary soundness. If the steel was not sound there would be no cavity, so that the quality of the steel is self-apparent.

Nine 15-in. ingots were taken (weighing about 3,600 lb. each) as they came through, each of which had the sand head and the writer's improved method of feeding carried out on them. After the ingots had cooled down, the hollows or cavities in the sand heads were filled with water, then the water poured out and carefully measured. Table I shows the results obtained.

TABLE I

Ingot Number	Cubic Inches	Pounds of Steel	Percentage of Weight of Ingot.
1	457	128	3.57
2	549	154	4.30
3	457	128	3.57
4	457	128	3.57
5	472	132	3.68
6	488	137	3.82
7	518	145	4.05
8	579	162	4.52
9	488	137	3.82
Average.....	496	139	3.88
Maximum.....	579	162	4.52
Minimum.....	457	128	3.57
Weight of ingot, 3,600 lb.			

The average weight for the nine 15-in. ingots showed that 139 lb.,

with a minimum of 128 lb. and a maximum of 162 lb., passed from the head portion into the ingot itself. This percentage is represented by an average figure of 3.88 per cent. In other words, about 4 per cent., or 140 lb., of the total weight of the ingot or ingots cast passed from the upper or feeding head into the body of the ingot.

There could not be a more striking illustration of the quality of the ingots produced and of the value of this system. Even in the case of the minimum percentage weight of steel which passed from the head of the ingot itself, there is a weight of no less than 128 lb. of steel short in the head, and therefore present in the ingot itself, all adding to the soundness and proper feeding of the piping which would otherwise occur.

To show still more clearly the important information obtained from these experiments, let it be assumed that the cubic capacity of each of the 15-in. ingots in question was approximately 12,500 cu. in. Therefore, but for this feeding, there would be a general want of solidity, chiefly at the upper portion of the ingot, to the extent of say 500 cu. in., say 4 per cent. of the whole capacity. It is surely readily apparent why an ingot which is not fed must perforce be deficient in homogeneity.

It is not claimed that ingots made in the ordinary manner are deficient to the full extent of say 4 per cent. There is a feeding effect from the steel in the upper portion of the ingot, but it cannot be done efficiently, as the steel quickly freezes on the outside of the mold and on the surface of the liquid steel exposed to the air. Moreover, there is always an uncertainty as to how good or how bad is the resulting material. If the steel is piping very much, the trouble will be worse than when it is piping less. In any case, as the steel solidifies in an ingot of this size, the natural law of contraction demands that about 500 cu. in. has to be dealt with. The writer cannot see how this can be efficiently and cheaply met except by some such method as described in this paper.

While the results necessarily vary slightly, because the sizes of the head portion nearest the top of the mold formed in sand are not always uniform in length, as the steel shrinks down slightly more on the outside in some cases than others, on the whole the maximum and minimum figures of $4\frac{1}{2}$ and $3\frac{1}{2}$ per cent. of the total weight of the ingot having passed from the head into the ingot itself, show very uniform working; if the heads were absolutely the same depth in each case, there would be practically no difference.

Without wishing to exaggerate, it is easy to picture to oneself what would be the character of each of these ingots if not made and treated under the method now described. The piping would have probably run down the ingot itself, requiring a discard of probably 25 to 33 per cent.

Although water cannot be poured into the cavity of a red-hot ingot, yet the cavity can be determined in each ingot by a cursory examination

while at a red or yellow heat, involving only a few seconds of time. It will therefore be seen that every ingot can be readily checked by such cursory examination.

While in ingots made in the ordinary way as above mentioned a certain amount of the fluid steel passes from the upper portion to the lower, still in so doing it is robbing the quality of the upper portion of the ingot itself, which has no fluid metal above it to feed or take the place and supply the deficiency thus created. It will readily be understood therefore why the upper portion of ingots is so seriously affected as regards their soundness, also why segregation occurs. The occurrence of these defects varies according to the type of steel, whether rising, semi-rising, or settling nature, as shown by Plate IX.

Again referring to this question of the cavities, if, as proved by these experiments, in the ingots made under the writer's system the metal in the sand head portion in descending has without doubt filled or prevented the formation of what would otherwise have been unsoundness, piping, loose structure, or segregated material, in unfed ingots made in the ordinary way there must be steel of loose structure; if not, then in many cases absolute unsoundness and segregation.

Moreover, and this is a most important point, the steel in the "fed" ingot being maintained fluid in the head portion, continues to exert its ferro-static pressure, whereas with ingots made in the ordinary way the ferro-static pressure on the center portion of the ingot is so slight that it produces very little beneficial effect. Further, without the feeding head above the ingot proper, the outside of the ingot in the ordinary ingot mold becomes rapidly chilled and frozen, so that it cannot contribute its proper share to the feeding of the remaining portion of the ingot. It is not therefore to be wondered at that rails rolled from the *A* and *B* portions of an ingot made in the ordinary way are liable to unsoundness or piping or both, and are also often full of impure segregated material.

There would probably be more dangerous ingots but for the fact that the steel maker tries to avoid this type of steel, and aims to make steel which when poured into the ingot will not pipe. Nevertheless, he is still fighting against a natural law. If piping steel is checked or avoided, he runs the risk of producing unsound steel, especially in the upper portion of the ingot, more or less permeated with blowholes. Thus, owing to lack of feeding from the upper portion, the center, or that portion on the axis line of the ingot, must be of inferior nature, as the piping characteristics persist for quite a long way down the ingot. This, as before mentioned, is for the reason that owing to want of ferro-static pressure, the ingot lacks feeding from above, which in the system of casting ingots now described is maintained to a very late stage; that is, until or close upon actual solidification takes place. There is always fluid steel in the upper portion of the ingot to feed the piping and shrink-

age, both of which must occur, as they follow a natural law. This, too, is the reason why there is so little segregation in ingots made under the writer's system, and also explains why the ferro-static pressure is kept up to a very late stage. In fact, check or hinder ferro-static pressure, and segregation with its bad effects at once commences. In the case of "fed" ingots, the smaller amount of segregation which occurs takes place outside the ingot proper, that is in the head. This is well illustrated by the results shown in Figs. 4 and 5 of Plate I.

With steel of piping nature poured into the ingot molds and not fed, it need cause no astonishment to find that rails, even from *C* and *D* portions of the ingots, may be of material with loose structure, consequently weak if not actually unsound, thus giving inferior or bad results in service. This is shown by Fig. 3 in Plate I, which shows that with piping steel not properly fed, there is extreme danger of this pipe extending a long way down the ingot; in fact, in some cases it has been found to go as much as two-thirds the length of the ingot. Ingots have also been found in which the piping has apparently stopped, only to be resumed below the sounder steel.

The experiment carried out by the writer some years ago, by the pouring of copper into the upper portion of an ingot 15 or 20 min. after casting, showed how serious is this want of ferro-static pressure in the material situated on or near the center or axis line of the ingot in ingots which have not been properly fed. The copper finds its way down to the bottom of the ingot, although added 15 min. after casting. In any case, if there is no definite pipe at the bottom portion of such ingot, there is still material of loose or open structure, which means weak steel. Although this may not be apparent by fracture to the naked eye, nevertheless it exists and can generally be detected by an examination of the microstructure. In other words, notwithstanding that the product to be used may come from the lower half of the ingot, yet in unfed ingots it will be weak and not able to stand severe stresses. This is probably the real explanation of the serious breakages which sometimes occur in even *C* and *D* rails. Imperfect material is present; only time and sufficient working stresses are wanted to develop its existence and weakness.

It is true that some portions of the cavities in ingots have been measured, but probably not in the manner described by the writer.

Although in the examination of the top of an ingot cast in the ordinary manner and from steel which "settles," there is external evidence of some piping, this is irregular and varies considerably. Therefore, in the "best" ordinary ingot proper evidence is slight as to how much or how little the steel has piped. Dr. Dudley has pointed out in his interesting paper to the Institute on Piping and Segregation of Ingots of Steel and Ductility-Tests for Open-Hearth Steel Rails, read in February, 1913, that in such ingots the piping is divided into two kinds, the upper, or what

may be termed the visible pipe, and the lower, or hidden pipe, the extent and character of which can only be determined by cutting open the ingot. In the ingots cast under the writer's system, *all the cavity or pipe is open* and can readily be inspected from the top; its extent can be determined whether in the hot or cold condition. It is therefore not necessary to cut open the ingot. In other words, such cavity produced by the piping is "the outward and visible sign of an inward and spiritual grace"—"spiritual grace" in this case meaning "soundness."

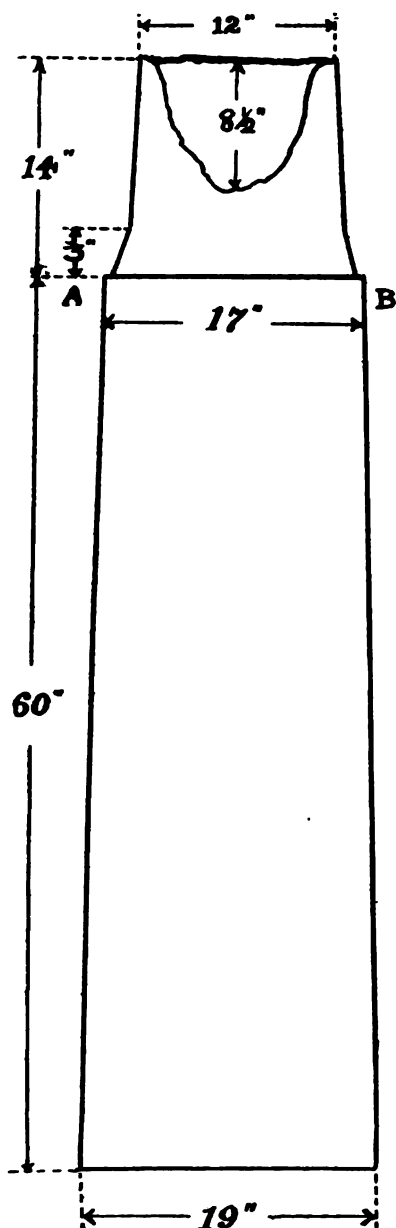
Figs. 1 and 2, Plate X, further explain this.

Fig. 1 represents an 18-in. ingot made on the writer's system, and as shown in Plate VII already referred to. *All the cavity produced by the piping* is easily visible and measurable from the top. If the ingot is allowed to go cold, the cavity can be measured and its cubic contents ascertained by filling such cavity with water, then pouring this out and taking its volume. If desired, the same object could probably be accomplished while the ingot was hot, in that case using a metal of suitable melting point. Such an ingot possesses no upper or lower cavity, it is all in one. The full characteristics of the ingot in this respect, and whether hot or cold, are known and determined by such cavity.

Fig. 2 shows the section of an ordinary 21-in. ingot made from steel which is of piping nature. It will be seen that there are two separate cavities, an upper and a lower one. While the former can be measured, the information obtained would not be of much practical value. As regards the latter, it is, so to speak, covered by a metallic diaphragm and cannot be measured except by cutting or machining open the ingot when cold. Moreover, it will be seen that the center portion of the ingot, that is the metal over and surrounding the central vertical or axis line of the ingot, is not sound for quite a long way down. Below where it appears to be quite sound to the eye there are still segregation results to be dealt with. In other words, a considerable portion of this ingot must be "discarded" or "cropped," either in the ingot itself or the rail produced therefrom, before a sound, safe rail can be obtained, that is, one which is perfectly sound not merely to the naked eye when examining a fracture of the ingot or the rail from such ingot, but is so when its microstructure is examined, or sulphur prints or etchings are taken.

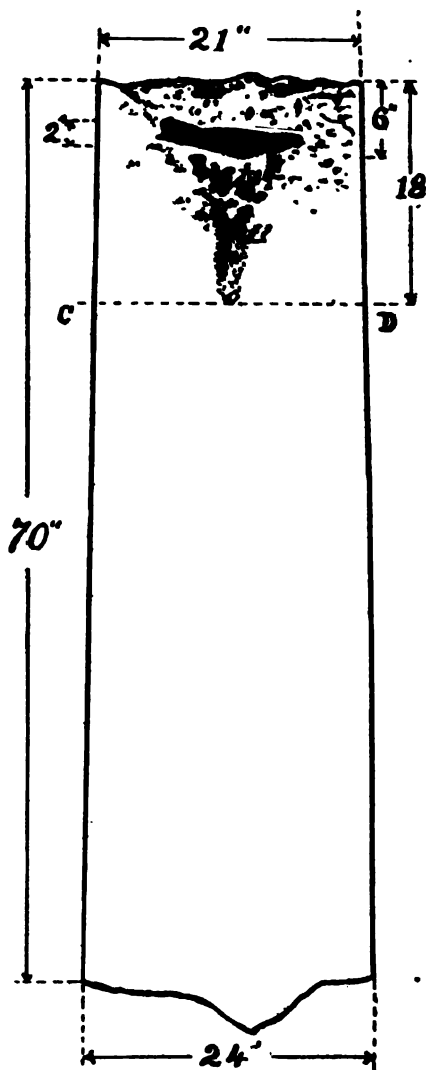
This real and true soundness is obtained in ingots made under the writer's system; that is, almost immediately under the cavity, and after a discard or crop has been taken of even as low as 7 per cent. in some cases, and certainly with 8 to 10 per cent. Therefore, such products as billets, bars, rails, sheets, etc., produced therefrom are practically sound at any portion of their mass.

This would appear to be a considerable advance as compared with ordinary practice, and even as compared with ordinary ingots of a char-



In the case of this ingot, all the metal is sound and free from piping and segregation below the line A-B.

FIG. 1.—LENGTH OF SOUND INGOT PROPER, 60 IN.



While the metal is sound below the line C-D, there are still segregation effects probably several inches further down.

FIG. 2.—LENGTH OF SOUND INGOT PROPER, 52 IN.

acter such as above referred to, which in themselves are certainly superior to many ordinary ingots made.

The ingot in Fig. 1, representing an ingot made under the writer's system, shows no unsound portion, that is to say, blowholes are entirely absent. About $8\frac{1}{2}$ in. from the top of such ingot, *segregation has disappeared*. Similar comparison with Fig. 2, representing what may be termed a high-class ordinary ingot, shows that at a point no less than 18 in. from the top there is still unsoundness. Moreover, below even the sound portion, there is segregated material which must be discarded before safe and sound structural steel can be obtained. It will be seen the discard of the former must be far lower, yet better and more sound material is produced.

The writer is aware that the above comparison is made between an ingot prepared under his system and an ordinary ingot which has been allowed to become cold. As Dr. Dudley has pointed out, there is considerable improvement in such ingots by handling them quickly while very hot. There is no doubt this is quite correct; yet in ingots cast under the writer's system, which can also be handled while very hot, it is difficult to see how an improvement can be effected in ingots which are already practically perfect.

At any rate, there certainly could not be a reduction in quality. In other words, if there was any difference in ingots made under the writer's system, the difference between "hot and cold" ingots would be in a favorable direction. The writer, however, thinks that these differences, that is, between the same ingots hot and cold, whether as regards the ordinary or the ingots made under his system, can hardly be very considerable, for after molten steel has once passed into the "solidus" as compared with the "liquidus" condition, there can surely only then be the ordinary contraction changes, or what may be termed "linear" contractions. These do not materially affect the volume of the cavity or the unsoundness, which if they exist remain practically as they are when the steel congeals into the "solidus" condition.

In view of the greatly increased service now met with on railroads in nearly all countries, resulting from heavier and more trains, higher speeds, whether freight or passenger, it will be seen that, in the nature of things, rails and similar products must be made from sound steel and from ingots each of which must be known to be as perfect as human ingenuity can accomplish. If this and other papers on the subject help to bring us nearer the goal and also help to remove what would appear to be a slur upon the metallurgist, then the labor involved in the many researches being carried out in this country and elsewhere will be well repaid.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at a meeting of the Institute. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y.

Comparison of Mining Conditions To-day with Those of 1872, in Their Relation to Federal Mineral-Land Laws

BY R. W. RAYMOND, NEW YORK, N. Y.

(New York Meeting, February, 1914)

THE situation in 1872, from the standpoint of the prospector, the locator, the possessory claimant, and the patentee of mineral land under Federal statutes, cannot be understood without a knowledge of the situation prior to 1866, and between 1866 and 1872.

The Situation before 1866

The western public domain acquired by the United States through treaties, as the result of conquest or purchase, was invaded after Marshall's re-discovery of gold in California, by an overwhelming multitude of prospectors and miners from all parts of the world. The mineral lands of the whole Pacific slope were practically unsurveyed. Congress, disgusted with the experiment of leasing mineral lands, which it had tried for 40 years, and abandoned in 1847, enacted no laws for the management of these public mineral lands, and the pioneers made their own laws governing mining titles. These local regulations applied at first to gulch-mining in the auriferous river-beds only; and they constituted a simple and practical system, adapted to the needs and means of primitive communities—significantly called "camps." They had the means of measuring distances, but not angles; they knew no property except personal property in the form of pickaxes, pans, supplies, camp-equipage, horses or mules, and mining rights. The earliest codes which they developed expressed what might be called the law of the lariat. With the lariat they measured the distance assigned to each miner along the gold-bearing gulch—a double portion to the discoverer, and a single portion to his successors, in the order of their coming. With the lariat, they hung, after such due process of law as was available, the rascal who stole a horse, or a bag of gold-dust, or a mining claim, or killed another man without giving him fair notice and a chance to defend himself. In these pioneer codes, adopted in mass-meetings and enforced by the same authority, two features concern us most:

1. They measured mining property by one dimension only. So many feet of the gulch, held by one man, meant a distance into either bank, and a distance in depth, extending as far as gold might be found.

2. Priority of right (and usually double extent of longitudinal dimension) was given to the discoverer, and, after him, to locators, in the order of location.

This system of mining titles ignored altogether the superior rights of the United States as owner of the land. As I have elsewhere shown,¹ this difficulty was solved by the common sense of the courts, which adjudicated controversies between trespassers on the public domain, according to their relative rights under local regulations, and subject to any future assertion of the higher rights of the United States.

Meanwhile, in many districts, the discovery of metal-bearing veins had inaugurated the new industry of "quartz-mining," and the pioneers simply applied to these deposits the rule already adopted for gold-bearing gulches: namely, they treated a vein as if it were a gulch; granted mining claims upon it, measured by a single dimension, and included in each claim all "dips, spurs, and angles," *i.e.*, all valuable mineral branching from the main vein between the two ends of the claim.

The Situation between 1866 and 1872

The Act of 1866 was an attempt to legalize the conditions which had thus grown up in the absence of Federal legislation. It declared the public mineral lands open to occupation and exploration, thus removing the guilt of trespass from prospectors and miners, and permitting for an indefinite period the exploitation of such lands, under the local regulations of the mining camps or of the States or Territories in which they were situated. This confirmed the prior right of the discoverer, which was the basis of all such local regulations. Moreover, the Act adopted the "law of the lariat," that is, the measurement of mining claims by one longitudinal dimension, and the possessory title of the locator to "dips, spurs, and angles." Finally, it provided for the purchase of permanent rights by patent from the United States, including certain rights within a given area of surface, required for mining operations on the vein located. This area was to be defined before the grant of the patent.

But unfortunately the Act of 1866 did not grant to locator or patentee any exclusive possession of the surface thus located, but only an "easement," or prior right of use. I believe that this feature of the Act, like the rest of it, was simply intended to legalize existing mining conditions, especially at Virginia City, Nev., which was in 1866 the most productive locality of "quartz-mining" in the West. The towns of Virginia City and Gold Hill were situated on and along the outcrop of what came to be known afterward as the great Comstock lode, though separate mines were then operated upon what were asserted to be separate lodes. The

¹ Our National Resources and Our Federal Government, *Trans.*, xlv, 617 *et seq.* (1912).

valuable buildings and building-lots of these towns would have been included in any grant of the surface to the mine-owners; and the Act was so drawn as to give the mine-owners only a sort of right of eminent domain, by virtue of which they could occupy such ground as they needed for mining purposes. Whoever saw the Comstock mines of that period, must remember the amazing complex of dumps, ore-bins, roads, shaft-houses, derricks and whims, interspersed with hotels, saloons, offices, stores and residences, exhibited at Virginia City.

But in the other mining districts which were soon discovered and developed, with a sanguine enthusiasm kindled by the wonderful bonanzas of the Comstock, the mere "easement" granted to the surface of a mining location was soon found to be an unsatisfactory protection to the locator. One of the most important of these districts—and the one which, I think, had most influence in bringing about the act of 1872—was that of Reese River, in Nevada, which was characterized by numerous sharply defined, narrow, frequently faulted fissure-veins, carrying very rich silver-ores, such as horn-silver, ruby-silver, etc. The locator upon such a vein had hard work, at best, to prove its identity in depth, beyond a fault which had cut it off, and thrown it to one side or the other. And he could not prevent other adventurers from starting shafts or tunnels in his neighborhood, and claiming as their own any bunch of rich ore that they might find. His only way to establish ownership was to push his own work underground until he reached the workings of such alleged discoverers, and then prove a practical continuity of ore from his prior location on the vein. Until that was proved, the hostile adventurers were not trespassers; they were simply exploring the public domain. And after it was proved, perhaps at great expense, he could rarely recover damages for the ore "innocently" taken by them. A writ of ejectment, expelling them from the stopes they had, perhaps, exhausted during the litigation, might be the only fruit of his victory.

This situation, promoting the practice of deliberate robbery in the immediate vicinity of every rich ore-body, was, of course, intolerable; and it is not surprising that the Federal court in Lander county, Nev., rendered a decision, so construing the Act of 1866 as to make it authorize a lode-locator to exclude prospectors from the surface of his location. John H. Boalt, the judge who made that decision, was a mining engineer as well as a lawyer, and afterward became one of the leaders of the San Francisco bar. His opinion was acute and forcible. Undoubtedly the Act ought to have meant what he construed it to mean. But his view was overruled by higher authority, though his arguments doubtless had their weight in bringing about the change inaugurated by the Act of 1872.

It is noteworthy that the Act of 1866 did not provide for placer-mining rights, or patents to placer-claims, although this was the earliest mining industry upon the public domain. The reason was that no special

difficulty had arisen as to such mining titles. The general permission to explore and occupy the public mineral lands, subject to local regulations, was enough, at that time, to satisfy that class of miners. But in 1870 an Act was passed amending and supplementing that of 1866, by providing that claims usually called placers, "including all forms of deposit except veins of quartz or other rock in place," should be subject to entry and patent. This had two important results: (1) It made placer-claims patentable, as they had not previously been; and (2) it included with placer-claims all deposits not "lodes," and included (as construed subsequently by the courts) other minerals than "gold, cinnabar, silver, or copper" specified in the original Act. There is reason to believe that both of these features, though desirable in themselves, were secured in furtherance of private enterprises—especially that of the so-called "diamond swindle," which was exposed in 1872. At least, I remember that the Act of 1870 formed part of the basis upon which this scheme was presented to New York capitalists.

The Act of 1872 was intended chiefly to remedy the above-mentioned defect in that of 1866, by granting ownership of the surface to a lode-locator. Its authors thought they were grafting a new feature upon the result of long years of growth; but they were, in fact, planting a new root altogether. The Act of 1872 was revolutionary. It made the mining right an appurtenance to the surface location, instead of granting an easement in the surface as an appurtenance of the mining right; for the reward of the discoverer it substituted the luck of the apex-possessor; and the title conveyed under it was subject to doubt and possible defeat as the consequence of new geological discoveries so long as the mining ground which it was supposed to cover might continue to be worked.

The extralateral right, supposed to be simply continued by the Act as a legacy from "the law of the lariat," suffered a considerable change through its dependence upon a new condition—the apex—which might or might not be correctly determinable at the time of location. This sudden introduction of a totally new basis of title led me to call the Act of 1872 "the law of the apex,"¹ a name which was universally adopted, together with that of "extralateral right," which I gave to the ownership of certain underground portions of a vein not vertically beneath its surface location. (The term "extralateral" could not have been applied under the Act of 1866, which attached no significance to the shape or position of the location as defining the mining right to which it was a mere appurtenance.) Without going into further detail as to the features of either Act, it may be said that both of them were dictated by the desire to respect as far as practicable the customs and self-made rules of miners

¹ *The Law of the Apex, Trans.*, xii, 387 (1883).

upon the public domain; and that such changes as were made were intended to meet existing conditions and satisfy the demands of influential constituencies and industries. It is impossible to explain by reference to the provisions of pre-existing European or Spanish-American codes the peculiar features of these statutes. They grew up out of local conditions, and were formulated by men ignorant of precedents and principles. Moreover, even those men were necessarily "opportunists," taking more or less blindly one step at a time. They never had a chance to frame a mineral-land law *de novo*. From the beginning, they were trying to satisfy the mining communities, and recognize as far as practicable existing local customs, remembering always that any attempt at sudden and essential change of such customs would be ridiculously futile, because incapable of effective enforcement. And of the revolutionary change which was thus made in several respects by the Act of 1872, both the authors of that measure and the communities affected by it were sublimely unconscious.

The foregoing demonstration of the "opportunist" character of Federal land legislation warrants the inquiry whether the conditions of 1872 have since been so changed as to justify new legislation in 1914.

The Situation in 1872

As I have said, the potential mischief continued in the Act of 1872 was neither foreseen nor immediately realized. The statute was welcomed in the region to which it applied as a much-needed protection to *bona fide* prospectors and their grantees, the investors of capital. No one expected it to produce a harvest of blackmail and litigation. Its immediate effect was to encourage the adventurous and speculative exploration of one new district after another; and, as the pioneer industry of mining blazed the way for the advance of all other civilized activities (though too often at ruinous cost to itself), the result was the conquest of a vast wilderness, and the creation of a new empire.

The situation in 1872 was this:

1. Indian wars had been practically removed as a serious element of danger, preventing the exploration of the public domain. Their doom was pronounced when the completion of the first transcontinental railway permitted the rapid movement of troops and supplies, so that hostile tribes could be pursued in winter campaigns.

2. Successive discoveries of rich placers or "quartz-mines" were causing excited stampedes of mining prospectors.

3. The price received for silver was such as to encourage silver-mining; and the silver-bearing deposits of such districts as the Cottonwood Canyons in Utah, White Pine and Eureka in Nevada, Owyhee in Idaho, etc., were being developed with wild enthusiasm. As we all know, certain classes of silver-bearing deposits offer outcrops of very rich min-

erals, admirably adapted to stimulate speculation. And the outcrops of silver-lead ores (already utilized in Utah, and soon to assume at Eureka, Nev., and at Leadville, Colo., immense economic importance) furnished, in their combination of lead, silver, and iron oxide, a material "smelting like butter" in the primitive furnaces of the period.

I am not here concerned with the exact dates of successive discoveries and developments in different regions, or successive advances in the mining and metallurgical industry of the West. My own public reports as U. S. Commissioner of Mining, etc., from 1868 to 1876, and many other authorities, may be consulted as to these details. What I wish to emphasize here is the character of the period just before and just after 1872, as one of new discoveries, new districts, new "processes," the exploitation of "bonanzas," and the enormous development of speculative investments in mining enterprises on the Pacific slope. It cannot be denied that the Act of 1872, with all its defects, stimulated this amazing continental development. Carlyle describes the tactics of the armies of the French Revolution as a process of "swarming"—a word which includes, in the German language from which he took it, the element of enthusiasm. The wilderness of our West was similarly overrun by the irresistible "swarming" advance of our mining pioneers, under the stimulus furnished, and in spite of the hindrances imposed (as we can now clearly recognize), by the Act of 1872.

The Present Situation

The conditions of to-day are the cumulative result of causes operating since 1872, among which the following may be named as the most important:

1. The demonetization of silver and its consequent fall in price. This naturally discouraged speculation in silver-mining, while it promoted economy in mining, handling, and reducing silver-bearing as well as other ores.

2. With the gradual exhaustion of rich bonanzas, the exploitation of large bodies of complex, low-grade ores had many important results.

- a. It was both cause and effect of the improvements in the methods and machinery of mining, transportation, and metallurgy, mentioned above.

- b. It employed larger numbers of men for longer periods, thereby creating greater and more permanent communities, and more numerous and varied industries, trades, and institutions. The general working of low-grade ores laid the safe foundation of civilization and progress in the new empire.

- c. It brought into profitable use the baser metals, which are more essential to human industry than the so-called precious ones. Yet this development of enterprises in which gold and silver were technically

by-products really increased the production of those metals. It is both instructive and amusing to read the utterances of the prophets of the last quarter of the 19th century, concerning the future of gold and silver. Our wise predictions were nullified, not so much by the discoveries of new producing districts, as by the new experimental illustration of the old, old general truths, that the existence of a bonanza of very rich ore may, and generally does, indicate the presence of a much larger amount of low-grade stuff, which, being temporarily too poor to "pay," is either not mined at all, or rejected after mining; that the "barren ground" and the waste-dumps of one period may be the mines of the next; and that he who, by utilizing neglected constituents, or reducing costs of mining, etc., enlarges the class of "workable" ores in an old district, may have performed a service equivalent to the discovery of many new ones.

d. This wonderful advance in the exploitation of low-grade ores inevitably diminished to some extent the importance of the old-fashioned "prospector," whose business was to find outcrops, make small surface-developments, and sell out to promoters, on the basis of sample-assays. Investors no longer cared so much for "rich" assays; they wanted large masses of low grade, and a secure title, neither of which the ordinary prospector could guarantee. He became, consequently, more and more a mere scout, whose first discovery was only a call for further investigation by geologists, lawyers, practical engineers, etc., before even the promoter, to say nothing of the actual investor, would take up in earnest the proposed adventure. Moreover, the great mining concerns employed their own scouts, and the old-fashioned prospector, operating on his own account, was almost left out of the new system. He has now well-nigh passed away, as have passed many other free-lances of the vanguard of progress. We may sympathize with him, but he had to go!

3. Legal conditions likewise have been profoundly affected by industrial progress. The ore-deposits of greatest importance were very different from the comparatively narrow and well-defined gold-veins of California and silver-veins of Nevada, which the law-makers had had chiefly in view; and the provisions of the law were applied with difficulty to the great ore-bodies in the "blanket-lodes," "chambers," and "mineral-bearing zones" of Utah, Colorado, and Arizona. Vast sums were squandered in litigation before even the meaning of the terms in the statute defining the extralateral right could be fixed by the U. S. Supreme Court.³

³ Prof. John B. Clayberg, in an able paper on this subject, published in the *California Law Review*, May, 1913, and reprinted in the *Engineering and Mining Journal* of Sept. 20, 1913, expresses the opinion that the law of extralateral right is now practically settled, but adds that "many complications, now unthought of, may present themselves" in the application of the principles established in 41 years of piece-meal interpretation.

Meanwhile, the owners of large mining properties have learned to protect themselves by executing mutual quit-claim deeds or side-line agreements with neighbors, or by purchasing outright such adjoining territory as threatens future conflict of title. In fine, the volume and cost of mining litigation has been greatly reduced, though the expense and difficulty of perfecting title by patent is still too great, and the nature of such title too indefinite. This improvement in the situation, being largely due to the practical abolition of the extralateral right by agreements between neighbors, is an argument rather for the repeal than for the continuance of that feature of the land-laws.

Indeed, all the changes in the situation above enumerated seem to me to call for such a repeal, even at this late day. But there is a new factor which may greatly hinder that simple and obvious reform. I refer to the movement for an entirely different treatment of what are called national resources. It seems likely that any attempt to amend the law of the apex will be seized as an occasion for proposing to abolish altogether the system under which, for half a century, the public mineral as well as agricultural lands have been sold to citizens. President Taft, it is true, in a public address advocating the operation of coal-mines and water-powers under Federal leases, disclaimed the intention of altering in this respect the laws concerning other mining titles, which he said were working well enough already! But President Taft's limited outlook and moderate suggestions will not satisfy the partisans of the new "nationalism." In my recent paper, cited above, I have discussed this question, and must reserve further statements concerning it, including replies to criticisms of that paper, for another place. I mention it here simply to express my apprehension that the movement for a practicable reform may fail again, as it has failed at least twice already, through the attempt to accomplish too much. The proposal to change many provisions of the present law (to say nothing of a total change of its purpose—namely, that of transferring the public lands to citizens, and the subsequent control of them to the Territories or States in which they are situated) will have, in my judgment, as it has had already, this result: that the opponents of any one of the proposed changes will unite to oppose them all, and the friends of any one such proposed change will be divided as to some of the others, so that it will prove impossible to make a clear and simple issue, upon which the needed majority could unite. This constitutes an important factor in the consideration of the subject assigned to me by the Chairman of the Institute Committee on Mining Law, at whose request I have written this paper.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at a meeting of the Institute. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y.

Notes on the Plastic Deformation of Steel During Overstrain*

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(New York Meeting, February, 1914)

§1. FOUR ASPECTS OF FLOW in the plastic deformation of steel by overstrain, such as punching, wire-drawing, tensile rupture, etc., are:

- (1) The *inter-granular*, i.e., the relative movements of the several grains, each as a whole;
- (2) the *intra-granular*, i.e., the relative movements of the masses of ferrite or cementite and pearlite within those grains;
- (3) the *intra-pearlitic*, i.e., the relative movements of the pearlitic ferrite and cementite; and
- (4) the crystal unit slipping, i.e., the travel of the minute units past each other, along the slipping planes, giving rise to the slip bands of Ewing and Rosenhain.

It may be objected justly that (2), (3), and (4) are in a sense "intra-granular," and that (4) is in a sense "intra-pearlitic." Hence clearness may be gained at times by calling these "Movements of the 2d, 3d, and 4th orders" respectively.

Tresca, and more lately Ewing, Heyn, Humfrey, Rosenhain,¹ and Stead have thrown great light on the mechanism of flow. We have sought chiefly to add to their discoveries by observing the intra-pearlitic

* A contribution from the Metallurgical Laboratories of Columbia University
Received Jan. 20, 1914.

¹ Tresca: *Proceedings of the Institution of Mechanical Engineers* (London), 1876 and 1878. Cf. Unwin: *Testing of Materials of Construction*, 1910, p. 40.

Ewing: *Journal of the Institute of Metals*, 1912, No. 2, vol. 8, p. 4.

Ewing and Rosenhain: *Philosophical Transactions of the Royal Society* (London), A, 1900, p. 353.

Heyn, Martens-Heyn: *Materialenkunde*, II A, 1912, pp. 219, 259 *et al.*

Humfrey: *Philosophical Transactions of the Royal Society* (London), A, 1902, vol. 200, p. 225. Iron and Steel Institute, *Carnegie Scholarship Memoirs*, 1913, vol. 5, p. 86.

Rosenhain: *Journal of the Iron and Steel Institute*, 1904, No. 2, vol. 65, p. 335. *Idem*, 1906, No. 2, vol. 70, p. 189. *Engineering*, 1908, vol. 86, p. 340.

Rosenhain and Humfrey: *Journal of the Iron and Steel Institute*, 1913, No. 1, vol. 87, p. 219.

Rosenhain and Ewen: *Journal of the Institute of Metals*, 1912, No. 2, vol. 8, p. 149, and 1913, No. 2, vol. 10, p. 119.

See also Longmuir: *Journal of the Iron and Steel Institute*, 1913, No. 1, vol. 87, p. 219.

movement of the 3d order, and the movements of the 2d order in the very violent throes of punching.

We have examined microscopically longitudinal sections through the fractures of tensile test bars of steel of 0.21, 0.40, and 1.45 per cent. of carbon, Nos. 2, 3, and 7 of Table I, p. 600, the longitudinal section of a wire-rod of bridge-cable steel, which has been drawn part way through a die in the first draft of wire making, No. 5; and vertical sections through holes punched sometimes through, sometimes part way through, tank-plate steel, and steel of 0.40 and of 0.78 carbon, in some cases with the usual tight-fitting die, and in others with a die much wider than the punch itself, Nos. 4 and 6, or in short with both cylindrical and conical punching. We have examined also the deformation in the previously polished upper surface of the tank plate, caused by both cylindrical and conical punching, Figs. 9, 10, and 11. The tensile properties of the tensile test bars are given in Table I, and certain details of the punching are given in Table II, p. 600, including the linear and cubic shortage of the punched wad, etc.

§2. THE INTER-GRANULAR movements are readily seen on a previously polished surface soon after overstrain starts in. Galy-Aché² points out that, with the passing of the yield point, comes the development of grains like those developed by etching. The uplift of these grains^{2a} on punching is seen clearly in Figs. 9, 10, and 11 of Plate 2. The displacements are greater in cylindrical, Fig. 10, than in conical punching, Fig. 9, which might well be foreseen; but there is a further and unexpected difference, that the matted area throughout which these inter-granular movements occur is wider in conical than in cylindrical punching. This probably represents the greater bending down of both upper and lower surface in conical punching. Further observations are needed to confirm this. Fig. 11 shows on a large scale one corner of such an uplifted grain.

§3. THE RELATIVE MOVEMENTS OF THE PEARLITE AND THE PRO-EUTECTOID FERRITE, in the punching of a $\frac{1}{4}$ -in. plate of steel of 0.40 carbon with a $\frac{1}{4}$ -in. punch, can be traced in Figs. 3, 4, 6, and 8 of Plate 1. Figs. 4, 6, and 8 represent the use of the customary tight-fitting die, or "cylindrical" punching, and Fig. 3 represents the use of a wider $\frac{3}{8}$ -in. die, or "conical" punching.

In each case the punched hole is of two parts, the parallel sided and the diverging sided, or the polished "cylinder" and the matte "bell," Fig. 5, but there is this striking difference, that with the narrow die the divergence begins very near the exit end of the hole, whereas with the wide die it begins about one-third way down from the entrance end.

There is the further difference that, with the narrow die, Fig. 4, the

² Galy-Aché, *Rev. Métallurgie*, Memoires, 1913, vol. 10, p. 588.

^{2a} We may surmise that the units which act as grains in this uplift represent what were the austenite grains before austenite-pearlite transformation took place. The massing of the ferrite would be greatest in the boundaries of these grains, and hence these boundaries would be the planes of least resistance.

elongation of the individual ferrite and pearlite masses into hairs or threads is more marked, but that the deformation has been confined to a narrower ring, than with the wide die, this latter difference reflecting the wider matting of the polished upper surface with the wide die. Thus with the narrow die the plate as a whole is less bent, but the pearlite and ferrite masses are more sharply bent, than with the wide die. Fig. 3 of course has no part comparable with the lower part of the edges of the hole in Fig. 4, in which the drawing out of the hairs has been extreme, for in Fig. 3 this part of the plate has been torn out in punching, and forms part of the wad.

Figs. 6 and 8, showing on a smaller scale the remaining region of cohesion and contact between wad and plate at stages during the progress of cylindrical punching, when taken in connection with Fig. 5, give some conception of the mechanism by means of which continuity is retained till the punch has moved nearly fully through the plate. This mode of flow seems like that of Tresca, a drawing out of the individual ferrite and pearlite masses into long hairs, but without implying great slipping of these masses as such, *i.e.*, without implying that the part of the pearlite hair with which a given part of a given ferrite hair is in contact at the end of the punching is a different part from that with which it was in contact initially. There has of course been such slipping in the movements of the fourth order, such exchange of partners, between the crystalline units of which the ferrite and pearlite masses respectively are composed, and no doubt a corresponding exchange on this same ultra-microscopic scale between the adjoining surfaces of ferrite and of pearlite.

This is especially true of the surfaces of contact between ferrite and pearlite in those regions in which the degree of elongation decreases rapidly as we pass radially away from the imaginary prolongation of the cylindrical surface of the punch, yet perhaps not more true of those contacts themselves than of every neighboring imaginary plane parallel to them. Where the degree of elongation or travel thus varies radially to the punched cylinder, so that one infinitely thin walled cylinder lengthens more than that adjoining it, there is an infinitesimal slip of one past the other; and when for infinitely thin walled cylinders those of crystal-unit thickness are exchanged, there comes a like slipping measurable in crystal-unit thicknesses.

But though in this sense the actual slip of any one surface is probably very slight, yet the integration of the very many slips at the very great number of surfaces leads to a great total of slip and of slipping friction.

Moreover, this drawing out of a ferrite grain into a ferrite hair means an enormous increase in the ferrite surfaces, and hence an enormous degree of emergence of ferrite crystal units, which initially were in contact with ferrite on all six faces within a given ferrite grain, to the surface of that grain where one of the faces of each unit is in contact with pearlite.

In short, one face of each unit which has thus moved to the surface of a ferrite hair has, in that motion, exchanged contact with a ferrite particle for contact with pearlite, and yet has preserved continuity, hypothetically through the interposition of Beilby's fluid state.

§4. TENTATIVE EXPLANATION OF THE MOVEMENTS IN PUNCHING. Our inquiries were not directed specially to the flow which occurs during punch-

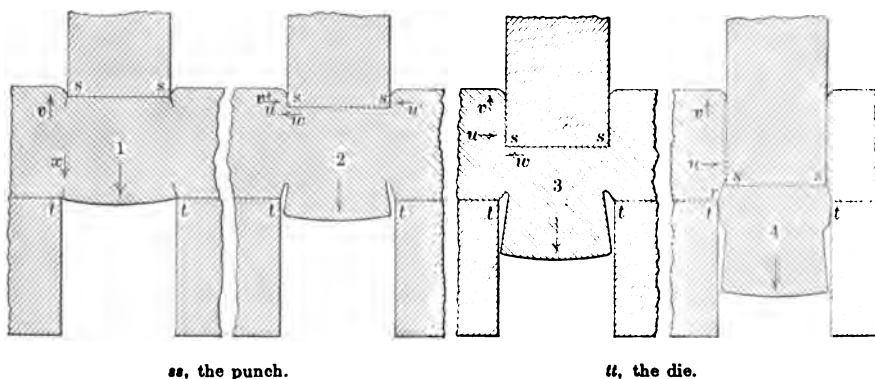


FIG. 1.—PROBABLE COURSE OF FLOW IN CYLINDRICAL PUNCHING.

ing, nor have we gone far enough to form firm convictions about them, but it seems well to record tentative inferences on this subject drawn from some rather striking phenomena.

The complete preservation of continuity, so beautifully shown by Tresca in the punching of ductile metals, is lacking in punching our

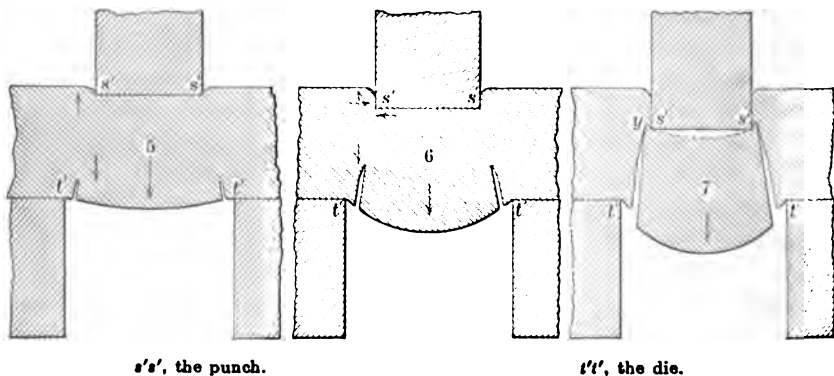


FIG. 2.—PROBABLE COURSE OF FLOW IN CONICAL PUNCHING.

0.40 carbon steel. There has, indeed, been great drawing out of the ferrite and pearlite, especially with the narrow die, into the long hairs, alternately black and white, from *a* to *d* in Fig. 4. But the distortion has exceeded the ductility of the metal, and started cracks, which in some cases are only abortive, as at *b* in Fig. 4, where a bell like that at *a* has started, with the tearing out of a triangle now seen in black. From the

lower right-hand corner of this bell a crack runs out into the solid metal. Another abortive crack is seen about $\frac{1}{4}$ in. above the top of the wad in Fig. 8. In Fig. 5, A, two thin nearly vertical cracks are seen, following the slight taper of the wad itself, back into the solid metal. As seen on a larger scale in Fig. 6, one of these cracks looks as if it were about to be modified by the further movement of the wad. In Fig. 8 there is an obtuse-angled incision into the wad, about $\frac{1}{4}$ in. below the lower edge of the plate, on this scale. This incision may have been formed from such a crack as is shown in Fig. 6, by the continuing moving down of the wad, the acute angle which this crack turns toward the wad gradually opening out into the obtuse angle of Fig. 8.

A tentative explanation of the various facts is sketched in Figs. 1 and 2, representing stages in cylindrical and conical punching respectively. If the metal were a perfectly mobile liquid, then the pressure would be the same in every direction and at all points. And though, because of viscosity, the pressure decreases both as the distance increases from the corners of punch *ss* and of die *tt*, Fig. 1, and as the direction deviates from that of the punching, there is yet very appreciable pressure in all directions.

Thus, it is to the upward component, *v*, stage 1, of that pressure, that we may refer the forcing up of certain grains at the surface, shown in Figs. 9, 10, and 11, and the matting of its initial high polish. Again, it is to the centripetal component, *u* and *u'*, stages 2 and 3, of that pressure that we refer the high polish or schlickensides in the cylindrical part of the hole, both with cylindrical and with conical punching (Fig. 5, Plate 1). That polish indicates that, while the punch was moving down, the metal of the plate was forced strongly against it, as at *u* and *u'*.

In strong contrast with this polish is the matte surface of the bell, agreeing with our inference that the bell results from a crack starting at or near the corners *tt* of the die.

Cracks tend most strongly to start where the deformation is greatest, at the corners *ss* of the punch and at or near the corners *tt* of the die, and once started tend to be extended by the downward movement of the wad. But the conditions tend more strongly to this extending at *tt* than at *ss*, and in conical than in cylindrical punching, as we will now explain.

As regards starting a crack, the conditions at *t* and *s* seem to be much alike, in one case the pressing of a sharp edge into the metal and in the other the pressing of the metal against a sharp edge, with the difference that the concentration of pressure is greater at *s* than at *t*, as is readily seen if we imagine a plate 1 ft. thick punched with a punch only $\frac{1}{4}$ in. in diameter. This difference represents the centrifugal movement of part of the metal which lay initially in the path of the punch, *i.e.* its radial movement, resulting in bulging the plate somewhat in the neigh-

borhood of the hole, so that the volume of the wad is less than that of the hole.

As between conical and cylindrical punching there is the difference that the pressure on the die corners is weaker in the former at $t't'$ than in the latter at tt , both because in the former the pressure is spread out over a longer circumference, and because in the former the tendency to flexure is less at the die corner t' , than at a point nearer the axis of the punch. This latter difference is readily seen if we imagine a $\frac{1}{4}$ -in. punch driven into a $\frac{1}{4}$ -in plate resting on a 3-in. die. Indeed the shoe-heel or burr, which projects down below the edge of the bell at the bottom of Fig. 2, suggests that here the crack started, not exactly at the edge of the die, but a little nearer the axis of the punch, either because of a local weakness, or because of the stronger bending moment there, or for both reasons. The direct measurements in Table II show that the final clearance between the die and the edge of the wad is about 0.05 in. At the time of the starting of the crack it was probably less, because the wad has probably narrowed as it bulged down in the further downward movement.

Apart from this, there is the difference between top and bottom, that the propagation of the crack started at s is opposed by the strong radial pressure w and u in stage 2, and in the stages immediately following the starting of the crack, an opposition which has no full equivalent at t .

It is to this strong centripetal pressure that we refer the arresting of the cracks as at b in Fig. 4, and in Fig. 8. One or more whole rings corresponding to these excisions are often seen in the polished cylindrical part of a punched hole. Here cracks, like that at s in stage 1, have started at various stages during the down-travel of the punch, each starting at the point where the sharp corner of the punch then lay. But their propagation has been arrested thus, and a little ring of triangular cross section has been torn out.

Now comparing conical with cylindrical punching, there is the difference that in the latter the strong pressure x , stage 1, opposing the propagation of the crack by holding together the metal transversely to the path of the crack, has no full equivalent at t' , stage 5. This pressure x on the shoulder of the crack tends to bend that shoulder down, through a progressive change from the initially parallel sided crack, to angles less and less acute as in stage 3, and later even obtuse as in stage 4. Of these stages the parallel sided initial crack is seen in Fig. 5, *A*, Plate 1; stage 2 is seen in Fig. 5, *B*; and stage 4 in the wad of Fig. 8, about $\frac{1}{4}$ in. below the bottom of the plate.

A stage between 3 and the obtuse-angled stage 4 is seen at the lower edge of the plate in Fig. 8, on careful observation. Note that the edge mn of the upper part of the projecting wad, though parallel to the edge of the punched hole, is about $\frac{1}{4}$ in. at its left. If the punch were now to move farther down, the edge of the hole would not be at n but at q . Hence the

re-entering right angle mnq should be interpreted as simply a stage between stages 3 and 4, in which the gradually opening crack happens to have been caught while at a right angle.

Because the vertical component of the pressure transverse to the crack is so much feebler at t' in conical punching than at t in cylindrical punching, the crack at t' is able to extend; and it thus creeps upward till it reaches a region in which that transverse pressure is strong enough to arrest it, for instance till stage 6. As the punch moves lower and lower, and the thickness of metal still resisting its further motion decreases, the pressure due to that resistance decreases simultaneously, and with it the component of that pressure transverse to the path of the crack, and with that also decreases the resistance to the further propagation of the crack, which thus continues creeping upward till, as in stage 7, it reaches the cylindrical hole already formed. Hence the fact that the wad is conical throughout, lacking wholly any cylindrical part representing the cylindrical part of the hole.

But even in cylindrical punching there may be a short conical or bell part at the very bottom. The genesis of this is suggested in stage 4. At a stage intermediate between 3 and 4 the solid metal of the plate is once again pressed against the sharp corner of the die, and this starts a new crack quite as the first crack in stage 1 started. But by this time there is so little remaining thickness of metal resisting the punch, and the pressure which its resistance sets up is therefore so slight, that the component of that pressure transverse to the crack is no longer strong enough to arrest its propagation, and hence it creeps upward till it reaches the down-growing cylinder.

This intersection releases the last of the resistance to the forward movement of the punch, save the slight frictional resistance against the already cut sides of the hole, and hence releases the pressure within the metal of the plate, and hence the pressure on the top of the little bell r of stage 4, leaving it sharp and straight edged as at a in Fig. 4.

This individual bell $\hat{a}$ of Fig. 4 has thus cut through. But had it started somewhat earlier, while there was still enough pressure to force its upper wall down, that down-forcing might well carry that upper wall down past the corner of the die, giving rise to a thin plate-bottom burr, such as usually forms in cylindrical punching. A preliminary examination of these cylindrically punched holes indicates that part of the circumference of the lower edge of the hole may have such a bell, and the rest of it such a burr; but that burr and bell do not occur in the same place. Indeed, if we have sketched their genesis aright, they are mutually exclusive.

The intersection of the bell-shaped crack with the cylindrical hole might conceivably occur at the very corner of the punch, but it might also occur somewhat above that corner, as was the case in our conical

punchings, leaving the wad-top burr y of stage 7. In cylindrical punching a like but smaller wad-top burr forms in like manner.

The bending down of the wall of the crack in conical punching, because of the continuing vertical pressure on its shoulder after it has already opened, is indicated in Fig. 3. Note that the wall of the bell is not straight. At the bottom it is nearly vertical, but inclines more and more strongly to the right as we pass up toward the cylindrical part.

The reason why conical punching weakens a plate less than cylindrical punching,³ in cases in which both are unpalliated by either reaming or annealing, is probably that it thus favors the propagation of the crack which starts at or near the corner of the die. At any given instant it is only the metal not yet cracked through that still opposes the downward movement of the punch. Hence the early and rapid propagation of the crack in conical punching reduces early and quickly the resistance to the entry of the punch. Moreover, the less resistance means less pressure within the plate, less friction between those parts of the plate already perforated and the punch which is moving through them, and less friction between the particles of ferrite and of pearlite which are dragged past each other from their initial equiaxed shape to the long zebra markings of Fig. 4.

In like manner the smaller pressure in conical punching, and the consequent smaller overstrain of the metal, might confine the damage to the metal in conical punching to a narrower ring.

These considerations furnish the explanation of the striking fact that though, with the narrow die, the distortion, as indicated by the length of the zebra markings, increases from top to bottom of the hole, with the wide die it decreases from the top of the bell down. Indeed at the lower end of the bell the arrangement of the ferrite and pearlite does not clearly disclose any distortion at all, and we need the presence of the heel-shaped burr at the bottom of the bell to assure us that there really has been material distortion.

Again, the decrease in the amount of deformation of the 2d order from top to bottom of the conical bell agrees with the conception that the crack which forms that bell starts at or near the edge of the die and creeps up, instead of starting at the edge of the punch and creeping down, because this deformation would naturally cease, or diminish very greatly, in any given region, at the moment when the crack extended beyond that region.

A comparison of these figures 3 and 4 shows us how much less reaming is needed to remove the distorted metal after conical than after cylindrical punching. If, for simplicity, the ratio of the diameter of reamer to punch is the same in both cases, then with the wide die the punch itself, in

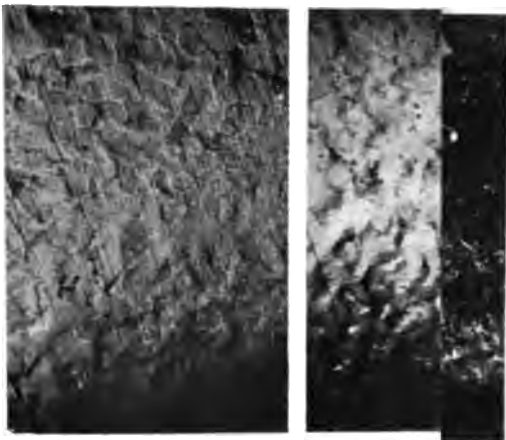
³ Howe: *The Metallurgy of Steel*, Table 122, p. 229.

THIS PAGE.

LIKE D

Bell

UPLIFT OF WHOLE GRAINS ON)
WIDE DIE. FIG. 9. $\times 42$ NARROW DIE



DISTORTION IN T

FIG. 12.— $\frac{1}{2}$ INCH FROM FRACTURE.

C
0.21

∇
 $\times 50$

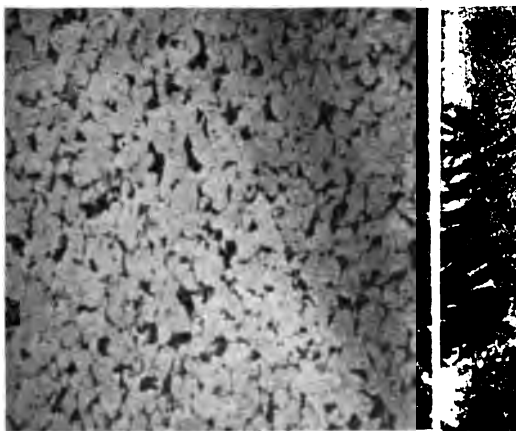
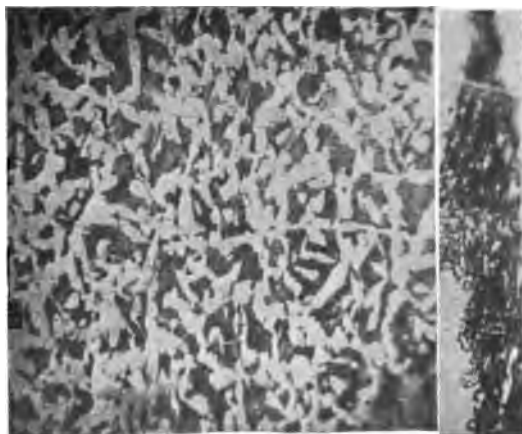


FIG. 14.— $\frac{1}{2}$ INCH FROM FRACTURE.

C
0.40

∇
 $\times 32$



PERSISTENCE OF PEARLITE.
CARBON 1.45. FIG. 23.
LAMELLE NORMAL TO FLOW



LAMELLE IN TENSILE RUP-
TURE. CARBON 1.45. FIG. 24.
LAMELLE PARALLEL ×1200



SAME IN PUNCHING.
CARBON 0.78. FIG. 25.
LAMELLE PARALLEL ×1200



DISTORTION OF LAMELLE
ON PUNCHING STEEL OF
0.78% C. FIG. 26. ×1200.



FIG. 27.—RE-EQUIAXING IN WIRE-ROD OF $0.75 \pm \%C$.
×50.



DEFORMATION OF PEARLITE IN WIRE-DRAWING.

BEFORE REDUCTION.

FIG. 28.



AFTER REDUCTION.

FIG. 29.



AFTER REDUCTION.

FIG. 30.



tearing out the bell, removes most of the metal which must needs be reamed out if a narrow die is used.

An even closer measure of the extent of the deformed and embrittled region could probably be had by examining the difference of potential, on a surface cut tangentially to the punched hole, the cutting plane being parallel to the axis of the punch.

§5. THE RELATIVE MOVEMENTS OF THE FERRITE AND PEARLITE MASSES IN TENSILE RUPTURE. Figs. 12 to 17, Plate 2, show the inequiauxing of these masses brought about in tearing a test piece in two in the common tensile test, both at the very edge of the fracture, and at a distance of $\frac{1}{2}$ in. from it. The micrographs are of course longitudinal sections. In Figs. 13, 15, and 17 the rough edge, with a wide plain black area below, is the fracture itself. Steels⁴ of 0.21, 0.40, and 1.45 per cent. of carbon are represented. To Rosenhain's admirable exposition we have but a few points to add.

How closely the deformation is confined to the necking area in the case of low-carbon steels is seen on comparing Figs. 12 and 13 with Figs. 14 and 15, for whereas the inequiauxing, or drawing out of the ferrite and pearlite masses, at the edge of the fracture, is naturally much greater in the 0.21 than in the 0.40 carbon steel, yet at a distance of $\frac{1}{2}$ in. from the fracture the 0.40 carbon steel is rather more inequiauxed than the 0.21. Indeed one would hesitate to affirm that any inequiauxing of the latter is shown here. On the "*delenda est Carthago*" principle we point out that the elongation in the inch within which rupture occurs represents the capacity of the metal to undergo deformation without rupture, *i. e.*, its fitness for hyper-elastic uses, the equivalent of the contraction of area but more closely measurable; and that the elongation in the remainder of the test piece, excluding this inch, represents the ability to endure deformation without losing elastic strength, and hence the ductility available for hypo-elastic uses, including the great majority of engineering services.

Though such a steel, in this special structural state, *i. e.*, after such heat treatment as this has received, has only about 29 per cent. elongation in 4 in. in the common tensile test, the elongation of the individual ferrite and pearlite masses shown in Fig. 13 is several hundred per cent. A comparison of these masses with the long ferrite and pearlite hairs of Fig. 4 shows how the degree of deformation endured without rupture is increased by pressing the deforming masses firmly together. In this punching the elongation of the ferrite grains is not in the hundreds but in the thousands of per cents. Figs. 5, 6, and 8 of Plate 1 indicate that even the upper part of the wad does not actually break away from the

⁴ These are the same steels which have served for many of our previously published experiments. The tensile test pieces were in each case $\frac{1}{8}$ or $\frac{1}{2}$ in. in diameter, with a measured length of 4 in.

sides of the hole till it has traveled far down that hole; that continuity persists thus through enormous local deformation.

This persistence is evidently due to the pressure with which each particle is held radially against its neighbor, contrasting strongly with the conditions in tensile testing, in which the withdrawal of each particle from its neighbor is not resisted externally in any comparable degree.

The slightness of the ductility of the steel of the 1.45 carbon, when its pro-eutectoid cementite has thus harmfully been assembled into a network, is reflected by the almost complete lack of inequiaxing in this network, even at the very edge of the fracture.

Fig. 16 illustrates the grave damage done by graphitizing the pro-eutectoid cementite, when this has been drawn out into long ghosts by rolling. The little equiaxed craters scattered through this field are the common ferrite-edged graphite masses resulting from the graphitization of cementite. The long white streak is, in like manner, ferrite which has resulted from this graphitization of a cementite ghost, and the black band with the white edges is a graphite mass, which is in effect a very formidable internal crack.

It is indeed striking that these cementite ghosts should be present in spite of the abundant opportunity for the diffusion of the carbon, for since this steel was rolled it has had two long sojourns well above the transformation range, one of an hour at $1,100^{\circ}$, and another of an hour at $1,000^{\circ}$.

§6. THE SHATTERING OF COALESCED CEMENTITE during plastic deformation is shown in Figs. 18 and 19. The long Saghalién-shaped vertical island of cementite, which is now shattered transversely into five fragments, was evidently a cementite reef formed by pearlite divorce. Its smooth upper surface distinguishes it clearly from the etch-figured sea of ferrite which bathes it. Whether or not all the crevices between its sharp fragments have been completely closed and welded by the inflow of ferrite or not, it is clear that, at the moment when any one of these transverse ruptures occurred, a minute crack must have formed. The ferrite evidently has a better chance to fill and heal these gashes, to weld across them, and to form strong adhesion with the cementite, under the slow deformation of the tensile test than in the sudden deformation of the notched bar impact test, for time certainly ought to favor these healing processes. Here, then, we have the justification of the assertion that the specific kind of brittleness, caused by the divorcing annealing of this low-carbon steel, is disclosed by the impact test more clearly than by the tensile test.⁵

§7. INTRA-PEARLITIC DEFORMATION. This deformation may be recog-

⁵ Howe: *Bulletin* No. 84, Dec., 1913, p. 2919; The Authors: *Transactions of the Cleveland Institution of Engineers*, to appear.

nized best by proceeding at once to the extreme case of punching, illustrated by Figs. 21 and 22, in each of which the direction of punching is vertical, as is shown by the zebra markings. Note the mass of shattered pearlite shaped like a pear, with its tail pointing upward. In the right-hand part of this mass, at *a*, the stratification of the pearlite is parallel to the direction of punching, and here the flow has elongated the pearlite parallel to its stratification. This elongation has narrowed the ferrite lamellæ proportionally, but the cementite lamellæ, being inextensible, have broken up into fragments which preserve roughly their initial direction.

As this thinning of the ferrite lamellæ suggests the closing of an accordion, so there is much to suggest its opening, with the moving apart

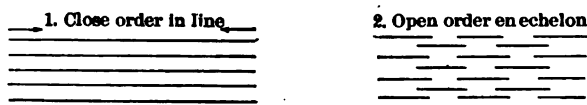


FIG. 31.—IF ALTERNATE STRATA ARE BRITTLE, COMPRESSION PARALLEL TO THE STRATIFICATION CONVERTS "CLOSE ORDER IN LINE" INTO "OPEN ORDER EN ECHELON."

of the cementite lamellæ by the foreshortening of the ferrite lamellæ at *b* in the lower part of this pear, where the pearlite stratification is normal to the direction of punching. The foreshortening of the plastic ferrite lamellæ is easily understood, but it is so hard to understand either how the brittle cementite lamellæ can thus foreshorten, or how they can, without breaking, endure the flow of the ferrite lamellæ between them and along their faces, that we should receive this suggestion with caution.

One may be less skeptical toward the like suggestions of the opening of the accordion, and the implied foreshortening of the ferrite lamellæ, in Fig. 19, because in the lower part of this pearlite mass several of the cementite lamellæ lie *en echelon*.

This suggests that the widening of the ferrite "lines," speaking militarily, has tended to move the cementite "lines" into more "open order," but that the shortening of the lines which this widening implies, though it is readily obeyed by the plastic ferrite, could not be followed directly by the rigid cementite, which instead has broken into "squads" in "*en echelon*" order, as sketched in Fig. 31.

This arrangement *en echelon* is seen also in the lower part of Fig. 19, a longitudinal section close to the fracture of a tensile test piece of 0.21 carbon steel. Because this area is close to the edge of the punch, it has bent down like a snow cornice. Though this bending gives the ferrite lamellæ nearest the edge a look of having been narrowed, so that the cementite lamellæ are brought closer together, yet at a distance of $1\frac{1}{2}$ in. from the edge of the hole on this magnification it seems to have

opened the accordion, *i.e.*, to have increased the distance from cementite lamella to lamella, implying a thickening of the ferrite lamellæ between them, and with that thickening a foreshortening, which tallies well with this *en echelon* arrangement.

What is even more striking in both of these figures is the apparent bending of the cementite lamellæ without breaking. The curving and continuous change of direction of the pearlite stratification from *a* to *b* of Fig. 21 is quite foreign to the natural habit of pearlite, and seems due to some eddy movement of the whole region. Much sharper curvature of the strata is seen in the upper part of Fig. 19, where the right-to-left compression has crumpled the stratification up into a W shape which is certainly artificial. Though one cannot be sure that these individual cementite lamellæ have not broken in thus distorting, it is certain that some of these lamellæ in Fig. 19 have bent almost to a U without breaking. A striking example is the lamella marked *c*.

That these extremely thin lamellæ of cementite should thus bend without breaking, though the thick cementite island of Fig. 18 has broken, is natural, reminding us of the great flexibility of sufficiently thin threads of slag-wool or glass, substances which in thick masses are so inflexible. Curving of the pearlite through flow is suggested by the left-hand part of Rosenhain's Fig. 19,⁶ but without clear indication as to whether the cementite lamellæ have remained unbroken through this bending.

Fig. 22 shows what we have called a "laccolite," *i.e.*, an intrusion of pearlite into the strata of ferrite with which it was initially interstratified. If not strictly a laccolite, it is like true laccolites in being arrested and not breaking through to the surface. Here the transverse component of the flow has forced an intrusion of pearlite into three parallel layers of ferrite, and indeed clear through the left-hand layer. What has become of the ferrite displaced by the intrusion of pearlite into the right-hand ferrite stratum is not clear.

Another unusual form of pearlite, cellular and recalling lebeburite, is shown in Fig. 7, Plate 1. Here the orientation of the etch figuring of the ferrite is not only very constant, but alike in these two ferrite bands, as if it were due to the pressure or the movements in punching.⁷

Disruption of the pearlitic cementite in punching, by translation transverse to its stratification, is shown in Fig. 26. Though the general flow in the extra-circumferential metal is radial and away from the punch, *i.e.*, tending to narrow any strata which lie parallel to a plane tangent to the hole, yet such strata, when they lie in immediate contact with the punch, are dragged down by it, curving like the surface of water at the edge of a fall, so that their stratification is widened, *i.e.*, the cementite

⁶ *Journal of the Iron and Steel Institute*, 1906, No. 2, Pl. XLVI, following p. 224.

⁷ These markings may possibly be connected with the polishing of the specimen.

strata tend to move apart. In Fig. 26 the mobile ferrite has conformed to this local opening of the accordion, but the brittle cementite lamellæ have broken up into short fragments. Here the surface is so much curved that only a very narrow strip of it can be brought into focus at once.

In like manner Fig. 24, the longitudinal section through the tensile fracture of a 1.45 carbon steel, shows in its left-hand part an apparent opening up of the stratification, which lies transversely to the axis of the test piece and the direction of main flow, whereas in Fig. 23, also a longitudinal section of the same fracture, the pearlite, which is here stratified nearly parallel to the flow, is but little deformed.

Another case of the deformation of the pearlite in tensile rupture is shown in Fig. 20, a longitudinal section near the fracture of a tensile test piece of 0.21 per cent. of carbon, with an unusual pearlitic structure.

The intra-pearlitic movement during the wire-drawing of bridge-cable wire, of about 0.75 carbon, is shown in Figs. 28, 29, and 30. This rod, which was $\frac{1}{4}$ in. in diameter, was drawn part way through a die $\frac{1}{8}$ in. in diameter, the rear of the rod remaining unreduced. Fig. 28 shows the unreduced rod, and Figs. 29 and 30, which represent spots within an inch of Fig. 28 in this same specimen, are from the wire into which this part of the rod has been drawn. Fig. 28 shows the normal pearlite of the rod, Fig. 30 shows about the normal condition of the pearlite in the drawn wire, and Fig. 29 shows one of the least disturbed pearlite areas in that wire.

Though the pearlitic deformation is very marked in some of these cases, yet in others it is only slight even when the presumable deformation of the 1st and 2d orders is very considerable, indicating that the movement of the grains past each other, and the readjustment of the positions of the masses of ferrite and of cementite, may leave the stratification of the pearlite little deformed. This can be traced in the right-hand part of Rosenhain's micrograph, No. 19, just referred to. Here the deformation of the pearlite at the very edge of a tensile fracture is at most very slight.

The smaller general deformation of high- than of low-carbon steel would naturally create a smaller tendency to intra-pearlitic deformation, yet Fig. 24, at the edge of a fracture of a very high-carbon steel with 1.45 per cent. carbon, indicates that even in this the pearlite itself may open up much. This makes it all the more striking that the pearlite of Fig. 25 shows so little deformation, even under the abrupt deformation of the mass which should be expected here at the very edge of a punched hole. Other cases, Figs. 23 and 29, of slight intra-pearlitic deformation where the deformation of the second order is very great, have already been noted.

§8. EQUIAXING PHENOMENA. The contrast between the long ferrite ghosts in the left part, *L*, of Fig. 27 and the equiaxed ferrite network in

its right-hand part, *R*, is very suggestive. *L* is evidently much decarburized, so that the temperature of *Ar*3 for *L* is higher than for *R*. From these facts we may infer that when the rolling ended the temperature of *R*, which was absolutely higher than that of *L* because of the greater distance from the surface, was far enough above the *Ar*3 of *R* to permit the austenite grains to recover from the distortion caused by the rolling and to equiax. Further, it suggests that the temperature of *L* was within its transformation range, *i.e.*, below its *Ar*3 but above *Ar*1.

That it was below *Ar*3 is suggested by the great elongation of the white ferrite ghosts. For above *A*3 the re-equiaxing of the distorted austenite grains seems to be rapid, so that if the finishing temperature had been above *Ar*3 these austenite grains would have equiaxed, and the ferrite which they generated in cooling from *Ar*3 toward *Ar*1 would have formed an equiaxed network. Yet this indication is not decisive, because such ferrite streaks form even after apparently good opportunity for the equiaxing of the austenite.

That this finishing temperature was above *Ar*1 is indicated by the presence of some equiaxed cells at the extreme left. An equiaxed ferrite boundary can be formed only by expulsion from an equiaxed grain; so that these equiaxed boundaries consist of ferrite expelled from grains which at the time of that expulsion were equiaxed, and have remained so since, *i.e.*, there has been no rolling since that expulsion. But ferrite expulsion comes only between *Ar*3 and *Ar*1. Hence the rolling here must have ended above *Ar*1.

§9. ACKNOWLEDGMENT. This investigation has been carried out in part under a grant from the Carnegie Institution of Washington.

§10. SUMMARY. Four aspects of flow are distinguished, the movement (1) of individual grains past each other, (2) of individual masses of pearlite and ferrite relatively to each other, (3) of the pearlitic ferrite and cementite within the pearlite, and (4) of the crystal units along slip planes. (§1, p. 585.)

2. The inter-granular movements as shown on the previously polished upper surface of a punched piece are more severe, but apparently confined to a narrower ring on that surface, in cylindrical than in conical punching. (§2, p. 586.)

3. A study of the movements of the individual ferrite and pearlite masses during punching suggests a tentative explanation of the differences observed between cylindrical and conical punching. (§§3 and 4, pp. 586, 588.)

4. The corresponding movements in tensile rupture are examined. (§5, p. 593.)

5. The shattering in tensile rupture of coalesced cementite islands, arising from the divorce of the pearlite in low-carbon steel, is illustrated. (§6, p. 594.)

6. The intra-pearlitic deformation is studied. Elongation and compression parallel to the pearlite stratification lead respectively to drawing out the cementite lines into squads, and rearranging them *en echelon*. These cementite lamellæ sometimes curve greatly without breaking (§7, p. 594). A pearlite "laccolite" eruption through the ferrite layers, with which it was initially interstratified, is shown (p. 596). Though the pearlite stratification is often greatly crumpled and otherwise deformed, yet it sometimes remains little deformed at the very edge of a fracture (p. 597). Even in high-carbon steel this pearlitic deformation may be marked (p. 597).

7. Incidentally it is shown how the equiaxing phenomena may be interpreted. (§8, p. 597.)

Table I.—Chemical Composition and Tensile Properties of the Steels used in These Experiments

No.	No. of piece	Chemical composition				Tensile properties				Shown in figure No.
		C	Si	Mn	P	S	Tensile strength	Yield point	Elongation in 4 in.	
		%	%	%	%	%	lb. per sq. in.	lb. per sq. in.	%	%
1	$\frac{1}{4}$ -in. tank plate.	T2, T3								9, 10, 11
2	$\frac{1}{4}$ -in. round bar.	IV, 7	0.21	0.039	0.053	0.013	57,385	33,790	29.0	12, 13, 18, 19, 20
3	$\frac{1}{4}$ -in. round bar.	I, 1	0.40	0.103	0.161	0.012	69,900	22,480	23.01	14, 15
4	$\frac{1}{4}$ -in. plate.	I, 251; I, 252	0.40	0.103	0.161	0.014	0.012			3, 4, 21, 22
	$\frac{1}{4}$ -in. plate.	I, A, B, C, D	0.40	0.103	0.161	0.014	0.012			5, 6, 7, 8
5	$\frac{1}{4}$ -in. wire rod.	205	0.75 ^a							27, 28, 29, 30
6	$\frac{1}{4}$ -in. spring plate.	C1	0.78	0.108	0.26	0.011	0.013			25, 26
7	$\frac{1}{4}$ -in. round bar.	IX, 8	1.45	0.14	0.16	0.009	89,250	35,780	3.8	16, 17, 23, 24

Table II.—Details of the Punching of the Steel Plates Represented in Plate 1

Cylindrical punching									
C	%	Loss of volume of wad in punching ^a		Lengthwise compression of wad, per cent. of initial thickness of plate	Shortage of diameter of diameter of hole		Approximate clearance since between maximum circumference of wad and		Approximate clearance between inside diameter of hole and die
		By measure	By weight ^b		Top	Bottom	Die (inch)	Punched hole (inch)	
Tank plate (average of three holes).	low	4.7	10.2	0.4	1.2	1.2 ^{a-d}	0.0065	0.0015	$\frac{1}{4}$ -in. plunger
I, 251, C.....	0.40	4.6	14.5	2.4	1.2	1.2 ^a	0.0065	0.0015	$\frac{1}{4}$ -in. (0.26) die.
Conical punching									
I, 252, D.....	0.40	10.3	4.3	9.7	-2.0 ^c	7.0	0.025	0.0125	$\frac{1}{4}$ -in. plunger.
I, 252, E.....	0.40	10.0	9.1	6.5	0	8.3	0.0275	0.015	0.0125
I, 252, F.....	0.40	11.7	3.7	9.7	-2.0	9.1	0.0265	0.0165	$\frac{1}{4}$ -in. (0.385) die.

^a Reckoning volume of holes as 100.^b Taking specific gravity as 7.85.^c The top of the wad is 2 per cent. wider than the top of the hole.^d Not determined; the hole and wad are nearly cylindrical.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at a meeting of the Institute. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y.

Manganese Steel, with Especial Reference to the Relation of Physical Properties to Microstructure and Critical Ranges

BY W. S. POTTER, PITTSBURG, PA.

(New York Meeting, February, 1914)

THE proportions of manganese and carbon in manganese steel are familiar to all, because manganese-steel castings have been well known for a decade or more in this country. The same alloy has now become a commercial product in the wrought state, and, as not only rails and bars are rolled daily but a great variety of forged and otherwise fabricated

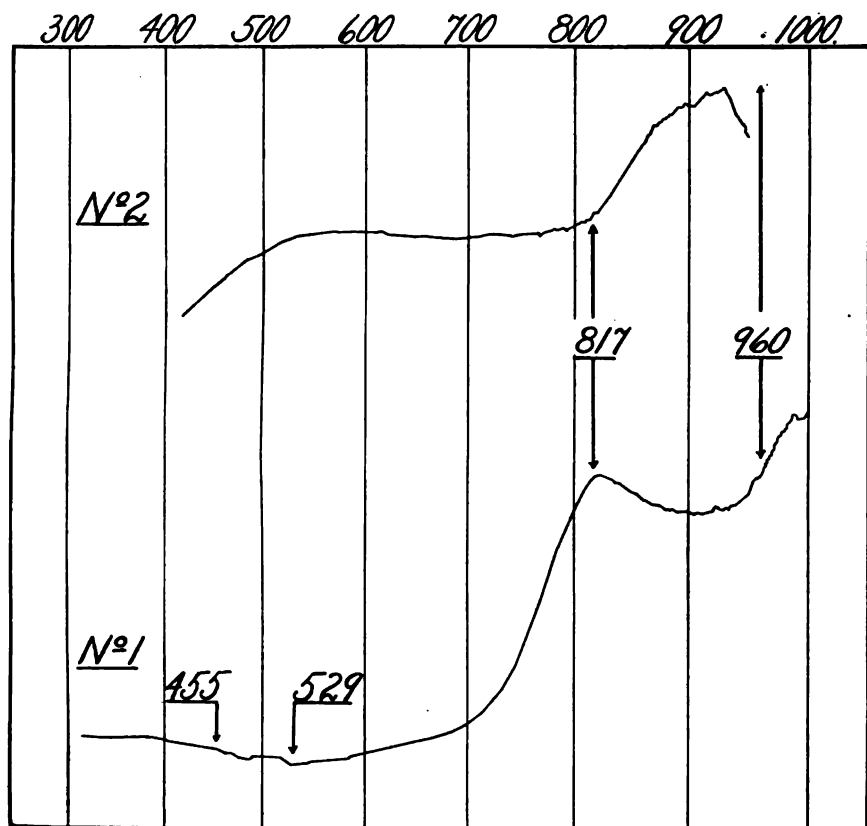


FIG. 1.—HEATING CURVES NOS. 1 AND 2. FORGINGS.

shapes are appearing, it may be interesting to mark the progress and, perhaps, to look a little closely into the nature of this important material of engineering.

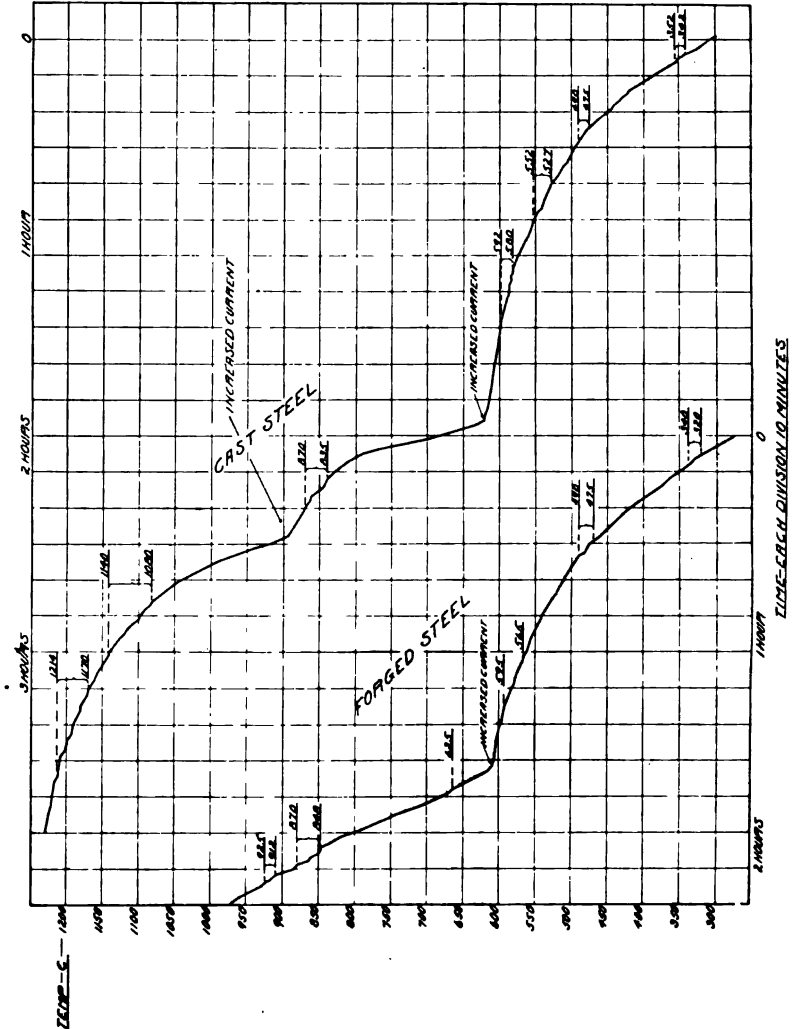
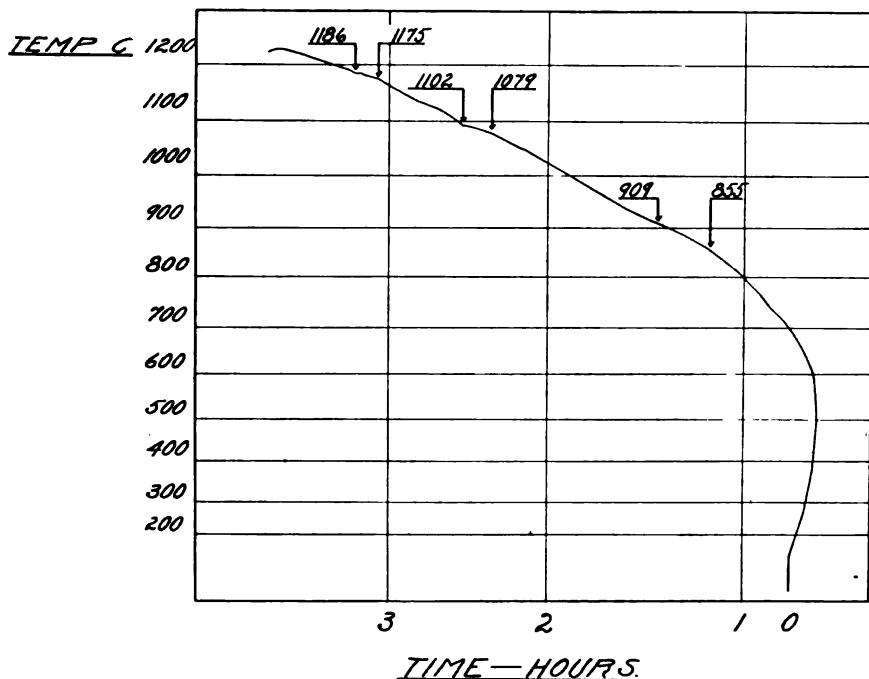


FIG. 2.—HEATING CURVE No. 3. CASTING AND FORGING.

Accordingly, this paper sets forth briefly the results of a few tests and experiments and endeavors to connect the retardations, for the most part slight, observable in heating and cooling curves, with changes in microstructures seen after various heat treatments of the metal, and to correlate these with physical tests.

Retardations in Heating and Cooling

Concerning heating and cooling curves, it should be noted at the outset that when the steel has once been so treated that it has a uniform austenitic structure, it may be heated and cooled either slowly or rapidly between, say, 0° C. and its melting temperature (ordinarily at between 1,350° C. and 1,375° C.) and the retardations observable are slight, and without many repetitions, these might well be attributed to vibration or



Corrections: At 800° C. add 15°; at 900° C. add 17°; at 1,000° C. add 25°; at 1,100° C. add 30°; at 1,200° C. add 28°.

FIG. 3.—HEATING CURVE NO. 4. CASTING.

Crucible Melt No. 8. Mn, 14.15; C, 1.51; Si, 1.05

error of instruments. Specimens taken from small castings, and also rolled or forged pieces, generally show but slight retardations.

However, when the metal is first slowly frozen, and then slowly cooled—for example, at the rate of cooling prevailing in the interior of even a small mill size ingot—the retardations are much sharper and greater. As the manganese and carbon percentages are raised, the separable constituents are increased, also by slower freezing, and cooling, the separations are increased. With greater separations the retardations are naturally greater.

The structural constituents of the series of metals from 9 to 20 per cent. manganese, and from 1 to 2 per cent. carbon (probably also of alloys considerably outside this range) are gamma iron, or austenite; cementite, a double carbide of manganese and iron; a eutectic of cementite and austenite; and what appears to be a second eutectic of lamellar structure. Structures which have the appearance of martensite, troostite, and sor-

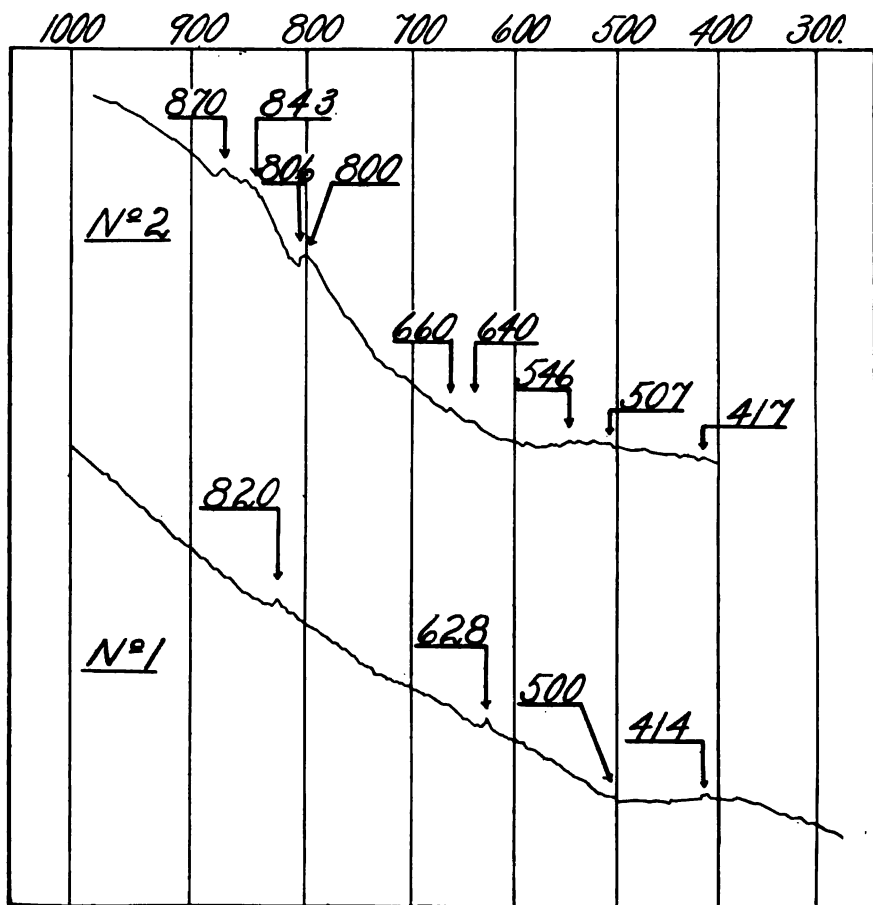


FIG. 4.—COOLING CURVES NOS. 1 AND 2. FORGINGS.

bite are also found in their proper relative positions. In cooling from the liquid, gamma freezes out as excess. Next, the lamellar eutectic freezes, although it is possible that the lamellar arrangement is due to mechanical break-up slightly below the end of freezing. Lastly, the residual liquid mixture of cementite and gamma iron freezes—this eutectic is white and is usually in part, or wholly, surrounded by the lamellar eutectic, although it sometimes appears within the austenite as a nodule from which the cementite radiates. As the temperature falls below 825° C. there is a

separation of the cementite from the austenite, giving rise to a variety of patterns, some decidedly martensitic. Troostite, and apparently sorbite, similarly result from the breaking down of the austenite as the temperature still further falls. On account of the very considerable difference in magnetic effects obtainable by cooling through, or heating in, different temperature ranges, it may be that the carbides separating in cooling at about 550° C., for instance, may not have the same composition as those

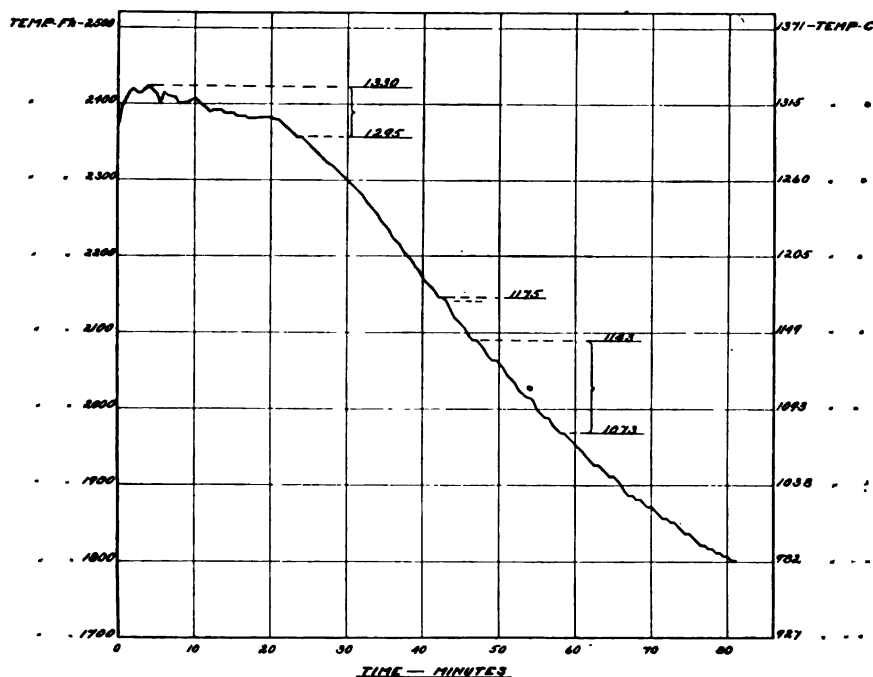


FIG. 5.—COOLING CURVE No. 3.

Seventy Minutes from the End of Freezing at Point in Axis 30 in. from Top of 5,500-lb. Manganese Ingot. Mn, 9.60; C, 1.01; Si, 0.084. Usually the eutectic in this alloy occupies less than 1 per cent. of the area.

separating in martensitic form at 825° C., or those separating as cementite plates at about 1,250° C. In the reheated steel during slow cooling, between 1,300° and 1,200° C., cementite separates out of the austenite as plates and needles radiating from a central nodule.

The retardations in heating and cooling are shown in Cooling Curves 1 to 5, inclusive, and Heating Curves 1 to 4, inclusive, Figs. 1 to 7, and in the heating and cooling curves of Crucible Melts Nos. 6, 7, and 12, Figs. 8 to 10. Unless otherwise stated, the specimens examined have the following composition: Manganese, 11.00 to 11.50 per cent.; carbon, 1.10 to 1.15 per cent.; silicon, 0.05 to 0.10 per cent.

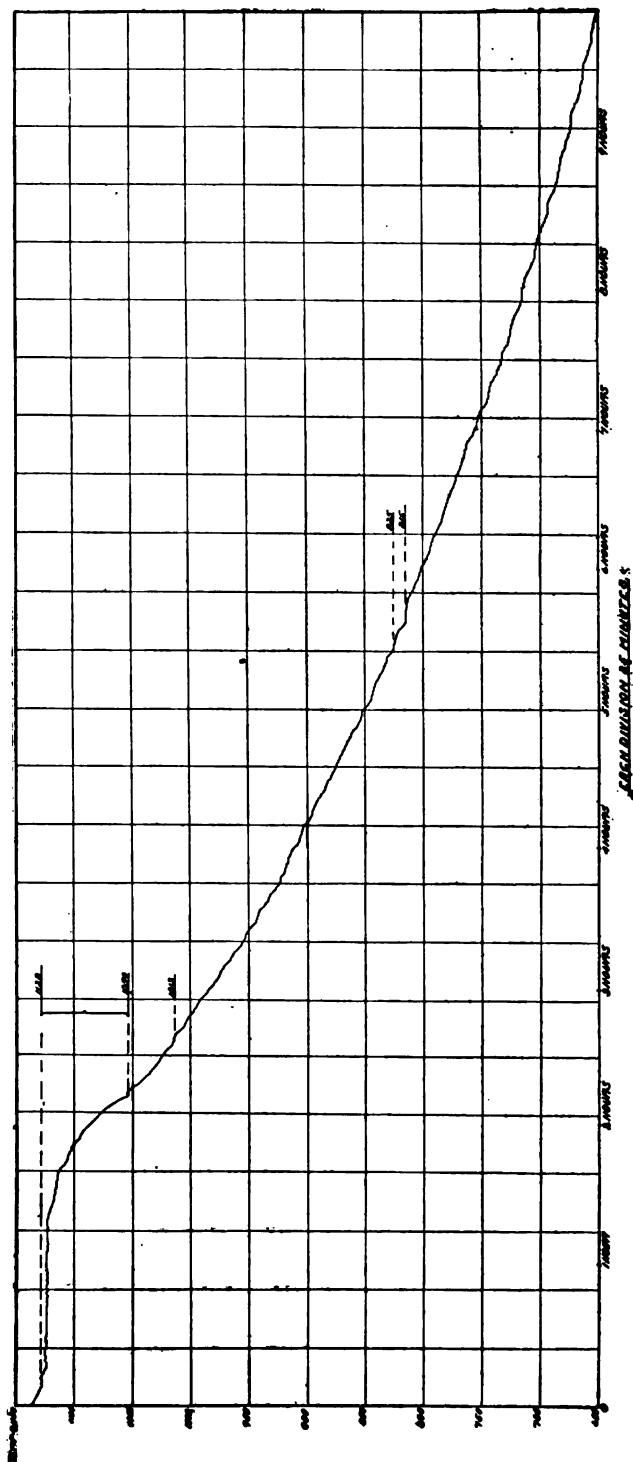


FIG. 6.—COOLING CURVE No. 4, TAKEN FROM BEGINNING OF EUTECTIC FREEZING. CRUCIBLE MELT, 150 lb. Mn, 11.30; C, 4.17; Si, 0.56.

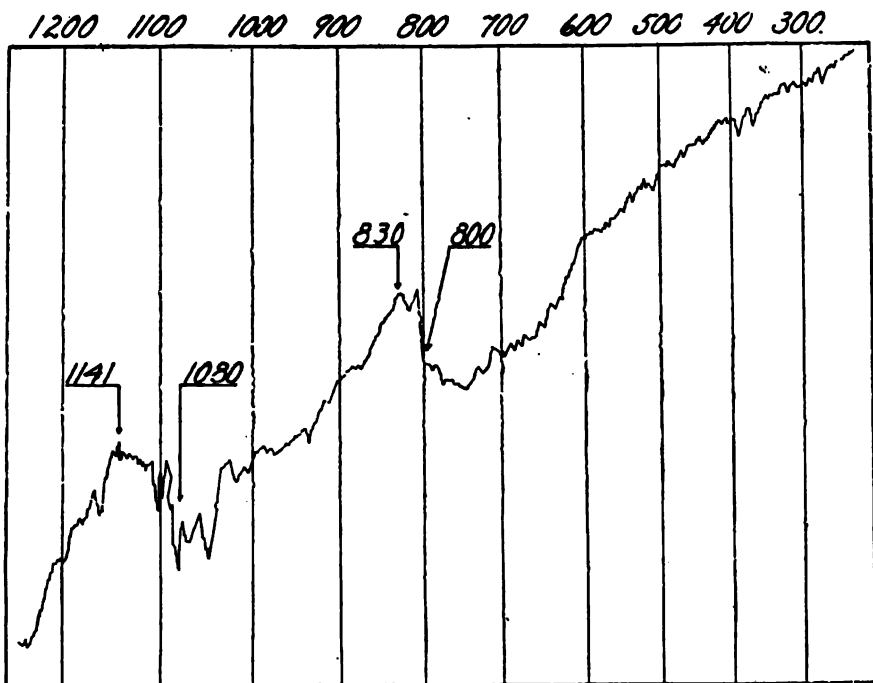
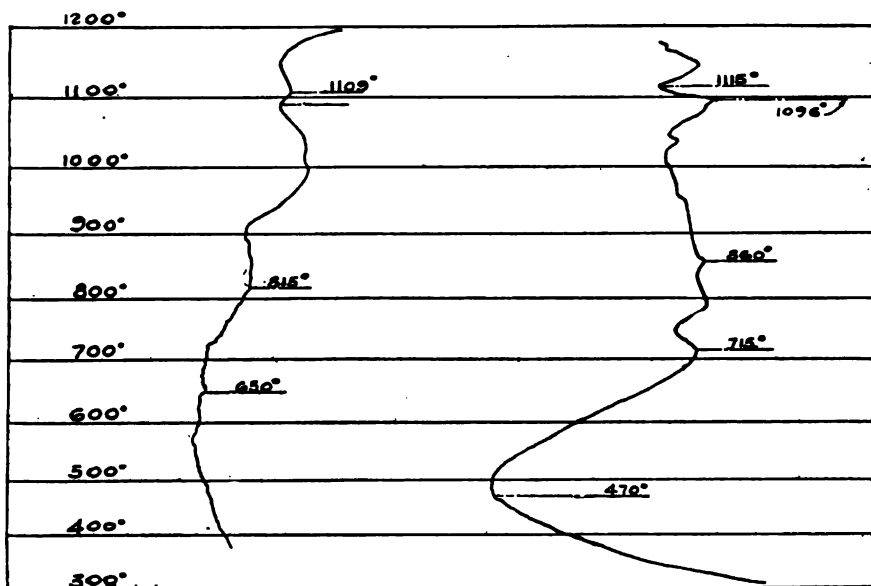


FIG. 7.—COOLING CURVE No. 5. CASTING.

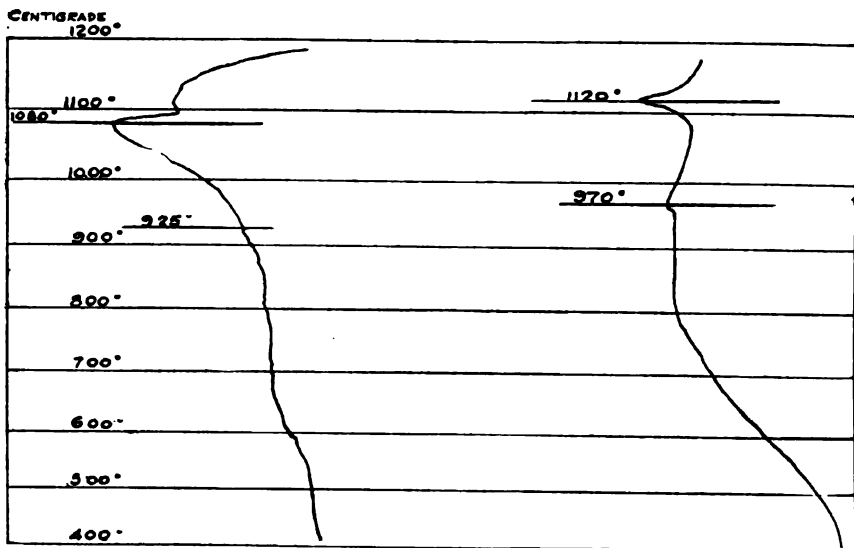
Specimen of Cast Ingot Metal. Mn, 11.30; C, 1.11. Rate of cooling 300°C . per hour. This curve was made with Saladin apparatus on specimens taken from a rail mill size ingot, and shows the retardation due to freezing of eutectic, and the retardation corresponding to the breaking down of austenite.

CENTIGRADE



First Cooling Curve. FIG. 8.—CRUCIBLE MELT No. 6. First Heating Curve.

These curves were taken with Saladin apparatus and show retardation corresponding to melting and freezing of eutectic at about $1,100^{\circ}\text{C}$., re-formation and breaking down of austenite at about 850° to 825°C .; also the heating curve shows retardation corresponding to the break-up of austenite by reversion at about 500°C . Specimen was water quenched after cooling from the heat of casting to about 950°C . Beginning at about $1,150^{\circ}\text{C}$., retardation indicates the beginning of melting of the mass. Analysis of specimen was: Manganese, 13.15; Carbon, 1.91; Silicon, 0.82 per cent.

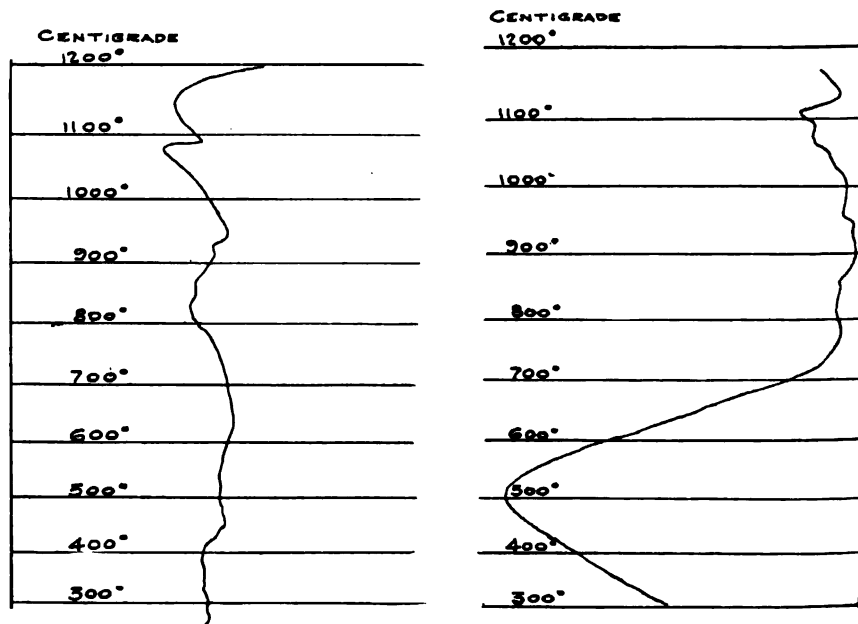


Cooling Curve.

Heating Curve.

FIG. 9.—CRUCIBLE MELT NO. 7.

This specimen has analysis: Manganese, 12.54; Carbon, 1.56; Silicon, 0.46 per cent., and shows by Saladin apparatus the melting and freezing of eutectic.



No. 1 Cooling Curve.

No. 1 Heating Curve.

FIG. 10.—CRUCIBLE MELT NO. 12.

Analysis: Mn, 25.35; C, 1.66; Si, 0.75.

In this very rich analysis there is more pronounced retardation between 900° and 1,000° C. than that seen between 800° and 900° C. Curves also show retardations corresponding to melting and freezing of eutectic, and in the heating curve there occurs the same retardation seen in heating curve of Crucible Melt No. 6, which is probably the break-up of austenite by reversion.

Conclusions from Heating and Cooling Curves.—The results of these heatings and coolings show:

1. That there is usually a well-defined retardation between 850° and 870° C., on heating, with corresponding retardation at 850° to 825° C., on cooling.
2. That a retardation at $1,100^{\circ}$ to $1,140^{\circ}$ C. on heating, is slight or well-defined, according to the composition of the alloy, and corresponds to a retardation on cooling at $1,125^{\circ}$ to $1,060^{\circ}$ C., which is equally dependent upon composition.

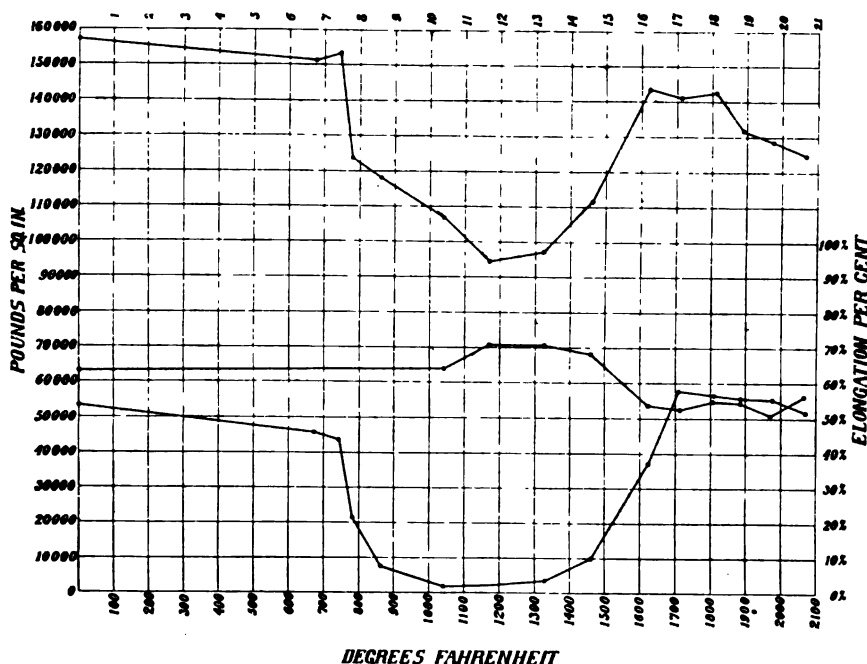


FIG. 11.—(SEE CORRESPONDING TABLE I).

3. That another retardation on heating at $1,200^{\circ}$ to $1,210^{\circ}$ C., which is also slight or well-defined according to the analysis, may correspond to slight retardations recorded during cooling, at $1,200^{\circ}$ to $1,170^{\circ}$ C.

4. That the retardation due to melting occurs at $1,350^{\circ}$ to $1,375^{\circ}$ C., and even lower with some alloys, while the retardations due to freezing occur at $1,370^{\circ}$ to $1,320^{\circ}$ C., and $1,300^{\circ}$ to $1,275^{\circ}$ C., respectively.

5. And, finally, that slight retardations on heating were recorded at the following temperatures, in degrees C.: 350 to 375 ; 450 to 470 ; 575 ; 675 to 735 ; 975 to $1,025$; and, on cooling, at the following temperatures, in degrees C.: $1,010$ to $1,030$; 925 to 950 ; 650 to 710 ; 525 to 550 ; 420 to 450 ; 325 to 350 .

TABLE I

(See corresponding Fig. 11)

Tensile Tests of Round Bars $\frac{3}{8}$ -in. Diameter in Pulling Portion

Analysis of Steel: Manganese, 13.00 per cent.; Carbon 1.02 per cent.

All bars quenched from heat of rolling.

Nos. 2 to 15 were also reheated for five minutes at the temperatures given, and then water quenched.

Treat- ment No.	Tempera- ture, Degrees Centigrade	Elonga- tion, Per Cent.	Breaking Strain, Lb. per Sq. In.	Elastic Limit	Remarks
1	.....	53.3	157,250	60,630	Crackle none or slight.
2	357	45.3	151,330	.....	Slight crackle.
3	394	43.7	153,720	.....	Slight crackle.
4	414	21.2	123,600	.....	No crackle.
5	460	7.8	118,000	.....	No crackle.
6	560	1.83	106,800	63,800	No crackle.
7	630	2.3	94,540	70,850	No crackle.
8	716	3.9	97,230	70,420	No crackle.
9	793	9.8	111,700	68,000	No crackle.
10	882	36.6	143,620	53,700	No crackle.
11	932	57.5	141,040	52,640	Slight crackle.
12	985	56.4	142,450	54,500	Slight crackle.
13	1,029	55.6	131,690	54,430	Bad crackle.
14	1,076	55.7	128,590	50,690	Bad crackle.
15	1,130	34.4	124,780	55,700	Slight crackle.

The Relation of Heat Treatment to Tensile Properties.

The effect on tensile properties of treating manganese-steel alloys at different temperatures, and especially at temperatures where retardations were recorded in heating and cooling, is shown in Tables I to IV, inclusive, with the corresponding curves of Figs. 11 to 14.

Remarks on Table I and Fig. 11.—These test bars were reheated in lots of ten. The short time at the maximum temperature of reheating apparently did not give the steel quite time enough to come fully to equilibrium. In consequence, the relation of critical temperatures to effect of heat treatment is somewhat obscured. Also, the manganese percentage was higher than that of the bars of Series 2, 3, and 4, which would tend to raise slightly the temperatures corresponding, for example, to the breaking up of austenite, and to its re-formation. Therefore, the first great

drop in ultimate strength and elongation, instead of being found between 350° and 375° C., comes between 394° and 414° C. The next break corresponds to the retardation at 450° C. with a loss of 13.4 per cent. in the elongation and 5,000 lb. further loss of ultimate strength. The next decided drop in values occurs after passing from 560° to 630° C., with lowest elongation at 560° C., and lowest ultimate strength of the series at 630° C., thus giving good confirmation of the reality of the critical point which was observed as but a slight retardation in the heating curves at between

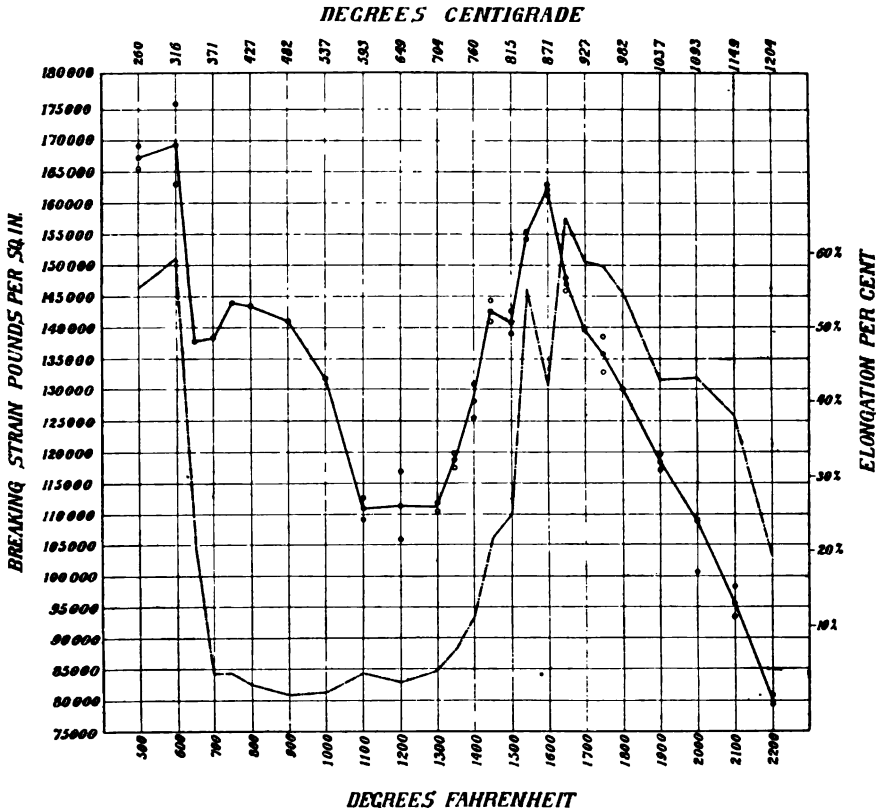


FIG. 12.—(SEE CORRESPONDING TABLE II).

Bars heated quickly to the temperatures given, held there for one hour, and then quenched in water.

550° and 535° C. The highest ultimate strength in the series for retreated bars is at 882° C., the first heat treatment above the retardation noticed at 850° C. The percentage of elongation is greater in those specimens treated at temperatures higher than that which gave the greatest ultimate strength, but, in noting the persistence of high elongation up to lot No. 14, at 1,076° C., the delaying effect of short heating should be remembered, and the "crackle" beginning at 1,029° C. should be given due weight, as great elongation in a generally cracking bar does not indicate a good condition.

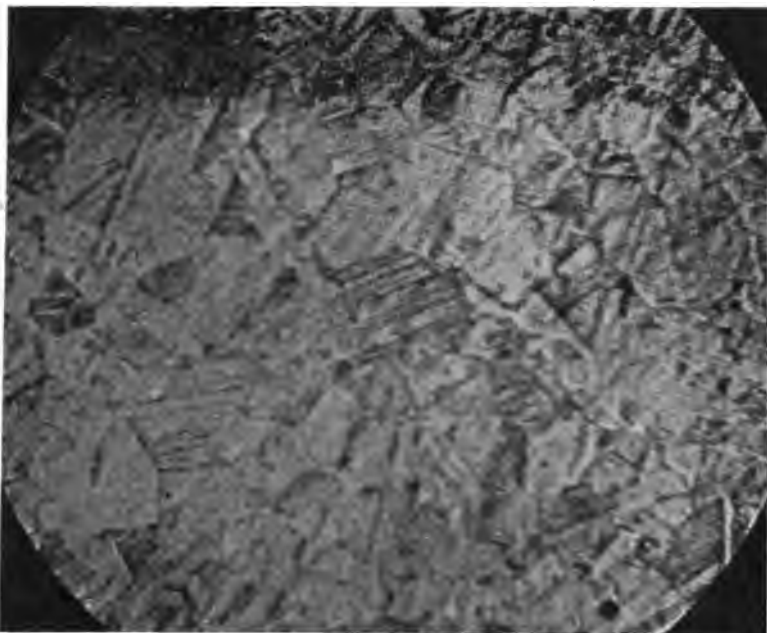
TABLE II

(See Corresponding Fig. 12)

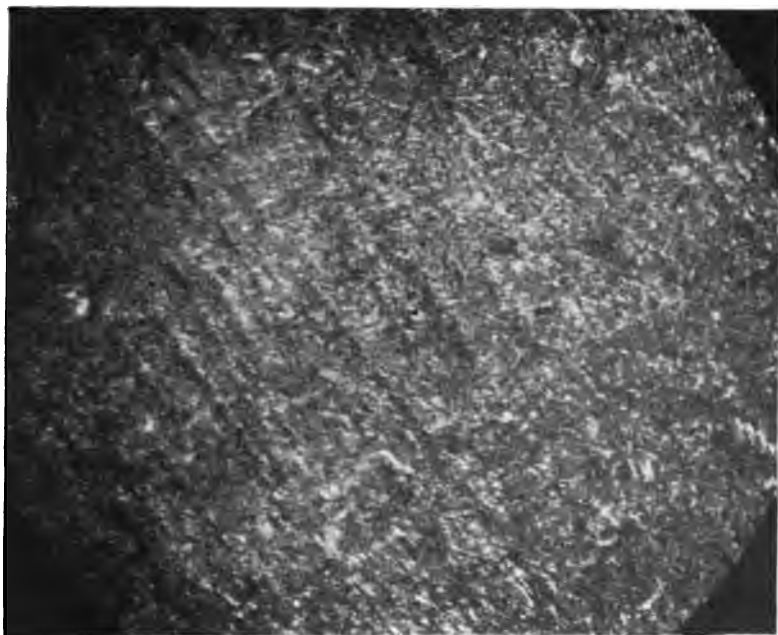
Tensile Tests on 3/8 in. Diameter Round Bars. Heated to Temperatures Given and Water Quenched.

Treat- ment No.	Heated 60 Min. At	Elonga- tion Per Cent.	Breaking Strain Lb. per Sq. Inch	Remarks	Micro No. All $\times$ 540
1	260	57.6 53.0	166,500 169,300	No crackle. No crackle.	417
2	315	63.5 55.0	176,000 163,100	No crackle. No crackle.	429
3	343	15.6 21.7	128,000 137,700	No crackle. No crackle.	419
4	371	3.6 1.6	138,200 116,300	No crackle; uneven values. No crackle.	420
5	399	3.7 1.0	144,100 112,400	No crackle; uneven values. No crackle.	421
6	426	2.2 0.7	143,500 102,200	No crackle; uneven values. No crackle.	422
7	482	0.8 0.6	141,100 129,100	No crackle; uneven values. No crackle; uneven values.	423
8	538	1.7 1.2	121,000 130,200	No crackle; uneven values. No crackle.	424
9	593	4.6 2.9	112,600 109,300	No crackle; nearly equal values. No crackle; nearly equal values.	425
10	649	2.0 3.1	106,000 116,800	No crackle; nearly equal values. No crackle; nearly equal values.	427
11	704	4.5 3.5	111,700 110,400	No crackle; nearly equal values. No crackle; nearly equal values.	428
12	732	6.1 7.5	117,400 119,700	No crackle; nearly equal values. No crackle; nearly equal values.	432
13	760	11.7 10.3	130,900 123,400	No crackle; nearly equal values. No crackle; nearly equal values.	461
14	788	21.9 21.7	141,000 144,300	No crackle; nearly equal values. No crackle; nearly equal values.	442
15	816	23.5 26.7	139,000 142,600	No crackle; nearly equal values. No crackle; nearly equal values.	443
16	843	57.4 52.8	155,500 154,300	No crackle; nearly equal values. No crackle; nearly equal values.	444
17	871	42.4 42.5	162,900 161,200	No crackle; nearly equal values. No crackle; nearly equal values.	445
18	898	65.0 63.8	147,800 145,900	No crackle. No crackle.	446
19	926	62.1 58.9	143,200 139,400	No crackle. No crackle.	447
20	954	56.0 60.3	132,800 138,400	No crackle. No crackle.	448
21	982	56.5 53.2	133,400 132,100	Slight crackle. Slight crackle.	449
22	1,038	44.1 42.0	123,700 121,200	Bad crackle. Bad crackle.	450
23	1,093	35.9 50.8	100,600 117,300	Bad crackle. Bad crackle.	451
24	1,149	35.7 40.9	93,200 99,200	Slight crackle. Slight crackle.	452
25	1,204	17.3 21.7	80,600 79,200	Slight crackle. Slight crackle.	453

Micrographs of Series 2 (see Table II).



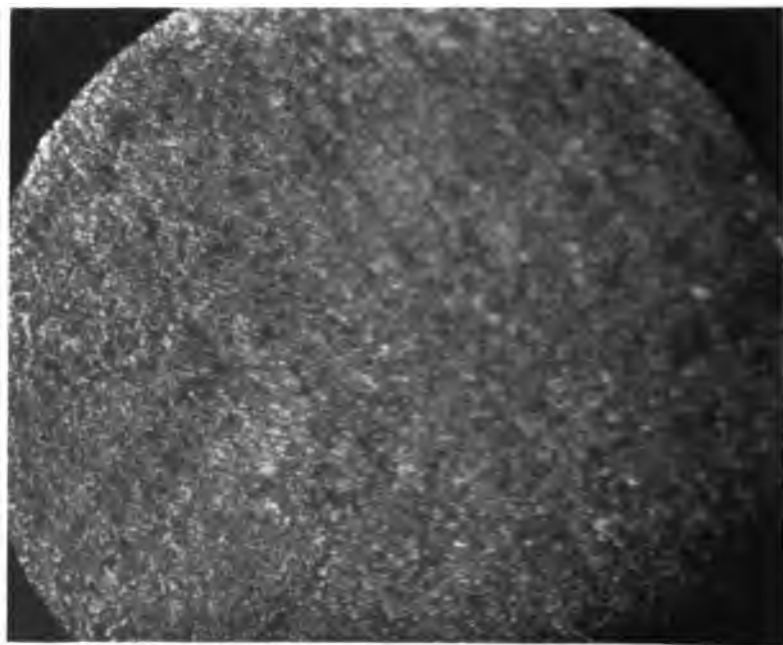
Treatment No. 1. 260° C. Micro. No. 417.—Uniform fine austenite of the usual appearance of the steel when quenched from the heat of rolling, showing that, up to 260° C., the condition obtained by rolling and quenching is not altered. Acid attack slow and even.



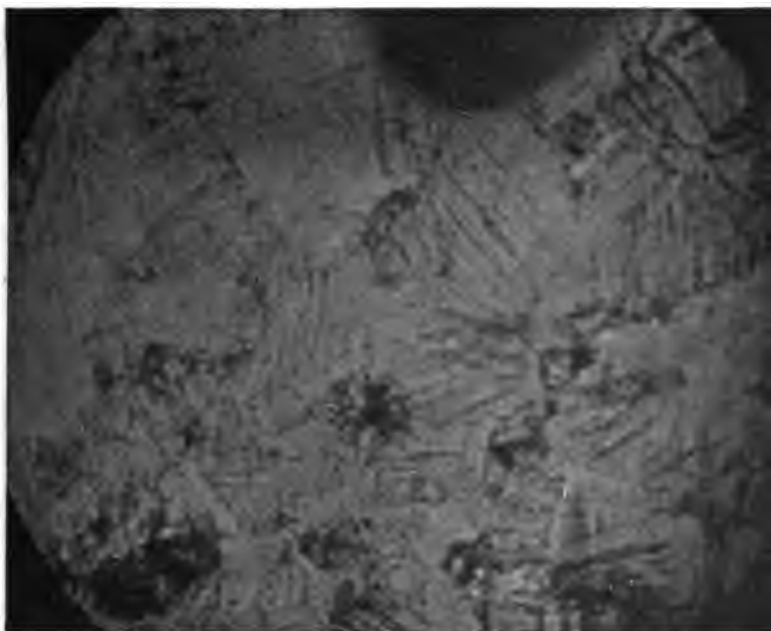
Treatment No. 5. 399° C. Micro. No. 421.—Austenite has disappeared and is replaced by a fine granular structure. A very fine network of lighter color beginning to form noticeably. Acid attack very rapid.



Treatment No. 7. 482° C. Micro. No. 423.—White network most pronounced. Acid attack very rapid.



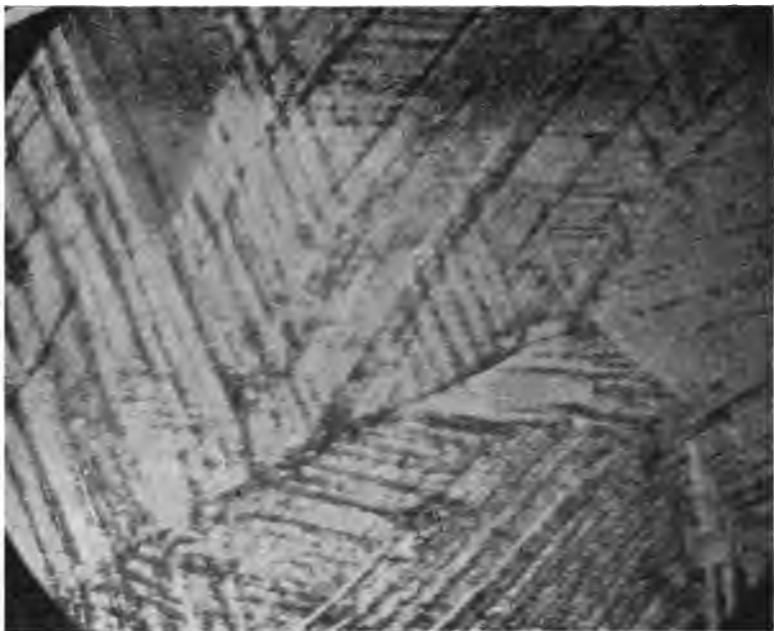
Treatment No. 9. 593° C. Micro. No. 425.—White network now very fine. Specimen has an appearance suggestive of moss. Acid attack rapid.



Treatment No. 16. 843° C. Micro. No. 444.—Austenite fairly well defined in places but not yet uniform. Acid attack very slow.



Treatment No. 19. 927° C. Micro. No. 447.—Large grains. Very characteristic coarse austenite. Good grain adhesion. Acid attack very slow.



Treatment No. 21. 982° C. Micro. No. 449.—Acid attack more rapid than preceding. Austenite breaking down at grain border, and etch deepest between grains.



Treatment No. 25. 1204° C. Micro. No. 453.—Note remarkably close adhesion of grains, and grain outlines scarcely traceable, except by cutting off of austenite structure lines, and slip planes after 60 min. etching in concentrated solution of picric acid in alcohol.

Lots 11, 12, and 13, heated at 882° and up to 985° C., show much the best results.

Remarks on Table II and Fig. 12.—Note the sharp drop from 315° C. through 343° C. to 371° C. The lowest percentage of elongation appears after passing the retardation range at 450° to 475° C., with a high but irregular tensile strength from 343° to 482° C., while above 575° C., the ultimate strength, although lower, is much more uniform. Values rise after passing 704° C. and the best tests are from 843° to 982° C., the greatest strength being at 871° C., and the greatest elongation in the re-treated bar at 898° C. As the temperature rises above 898° C., the values fall in a fairly regular way, as might be expected, with rapidly increasing grain size and diminishing density.

In this series (Series No. 2), there are three temperature regions where the metal is uniform austenite:

First, when, after water quenching from heat of rolling, the bar is not reheated to a temperature much above 300° C.

Second, when the bar has been reheated to between 850° and about 950° C.

Third, when the bar has been reheated to a temperature between 1,125° and 1,225° C.

In the first two regions, physical tests show the steel to be at its best for strength and ductility.

Between regions one and two, the metal is weak and brittle.

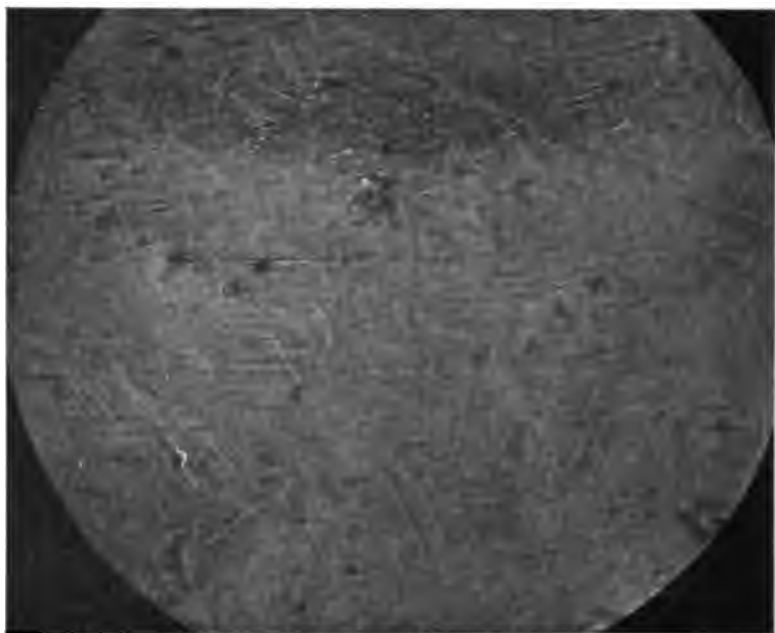
Between regions two and three, the specimen, when bent or stretched, cracks generally between the grains, showing a very low grain adhesion, and in a manner suggesting that, at this time, some brittle substance must have separated from the grain and lodged at the grain surface. In fact, a close micro-examination often shows a fine white line between grains of steel heated between ranges two and three, while acid attack is always deeper at the grain outline than it is in either range two or three.

Temperatures included in region three cover substantially the range which has been found useful for the heating of ingots for rolling.

Temperature Range of Martensite Formation.

A diversion at this point may indicate the character of structure lying in the range between austenite ranges No. 1 and No. 2; that is, in the range of low-temperature heat treatments where austenite has been lost and not restored and where the steel is hardest and has but little ductility.

For this purpose six specimens of series No. 1 are compared with a specimen of the same steel heated to 1,325° C. and cooled slowly to ordinary temperature. The results are shown in the following micrographs:



Micro. No. 13, 940 diam., quenched from heat of rolling bar. Uniform austenite.

(Treatment No. 1—Series No. 1.)



Micro. No. 8, 470 diam., reheated five minutes at 427° C.

Unequal acid attack. Austenite disappearing. Network of carbides appearing.

(Treatment between 4 and 5. Series No. 1.)



Micro. No. 34, 470 diam., 560° C., 5 min. etch. Austenite gone. Faint white network of carbides surrounding new grains having structure with fine white lines branching and intersecting at various angles. There is certainly room for the thought that this structure is martensite occurring in its proper position; that is, below the temperatures that produce austenite.



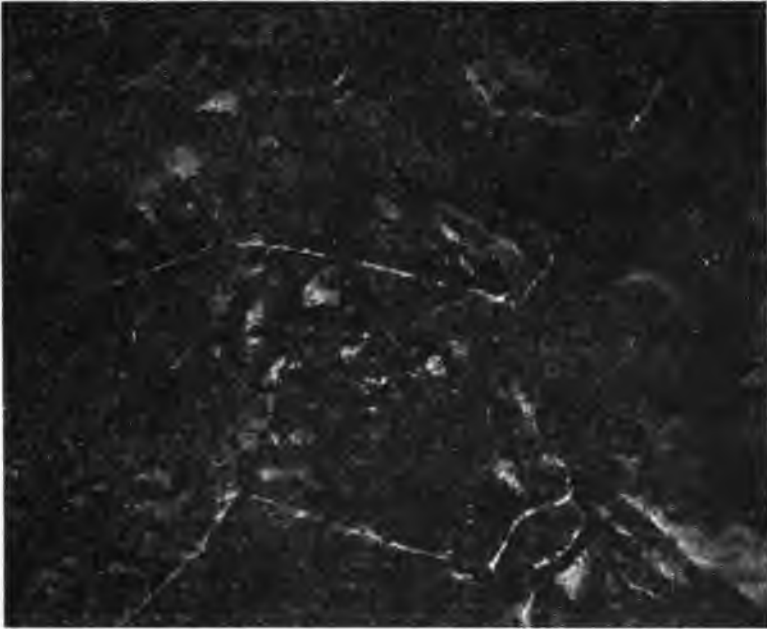
Micro. No. 36, 470 diam., 716° C., 15 min. etch. New structure forming within grains with large portion of surface still consisting of fine intersecting lines.



Micro. No. 37, 470 diam., 14 min. etch. Temperature 793° C. Resolution within grains almost complete; white network still showing at grain borders. High magnification shows new grain structure to be austenite.



Micro. No. 42, 470 diam., 31 min. etch. Temperature 895° C. Restored uniform austenite with no remnant of white constituent at grain outline.



Micro. No. 14, 950 diam. Slow cooled from 1,325° C. Carbide separation on grain border. Note form of white patches and grain structure resembling martensite.

Effect of Slow Cooling on Tensile Properties

The effect of slow cooling on manganese steel having 11 to 11.50 per cent. manganese and 1.10 to 1.15 per cent. carbon is shown in Tables III and IV and corresponding Figs. 13 and 14.

TABLE III

(See corresponding Fig. 13.)

Tensile Tests on $\frac{1}{4}$ -in. Diameter Round Bars, All Heated to 1,149° C. and Cooled at Rate of 55° C. Per Hour. Specimens Drawn and Water Quenched at Temperatures as Given

Treat- ment No.	Drawn from Fur- nace at	Elonga- tion, Per Cent.	Breaking Strain, lb. per sq. in.	Remarks	Micro. No.
1	1,149° C.	25.6	83,380	No crackle.	.....
2	1,093	21.0	84,890	Bad crackle.	.....
3	1,038	29.4	85,260	Bad crackle.	.....
4	982	29.8	82,790	Slight crackle.	.....
5	926	27.1	81,210	Slight crackle.	.....
6	871	25.4	79,510	Slight crackle.	.....
7	816	26.7	80,720	Slight crackle.	.....
8	760	24.6	71,500	Slight crackle.	.....
9	704	26.5	82,090	Slight crackle.	.....
10	649	25.1	81,345	Slight crackle.	.....
11	593	1.0	34,380	No crackle.	431-540
12	537	0.2	33,620	No crackle.	434-150 diam. 430-540 diam.

Remarks on Table III and Fig. 13.—Bars 1 to 10, inclusive, broke in part through the grains, showing fairly good grain adhesion. Bars 11 and 12 showed no breakages of grains, the fractures being entirely between the grains; while micro-examination showed in bars 1 to 10 no separations between grains; and in No. 11 a slight separation of carbide, and in No. 12 a broad silvery band of separated carbides between grains with a breaking down of the metal at the edge of the grains.

Remarks on Table IV and Fig. 14.—Note that, during slow cooling from 926° to 843° C., there is no considerable change in physical properties, while a sharp break occurs between 843° and 816° C., corresponding to the location of the retardation point at about 825° C. in cooling. Also note that the lowest ultimate strength is found after passing from 538° to 510° C., corresponding to the slight retardation frequently noted at about 525° C. in cooling, and that the lowest percentage of elongation

appears after passing from 427° to 399° C., while a slight retardation is often found at about 425° C. Also, the ultimate strength is within 500 lb. of the minimum for the series after passing 425° C.

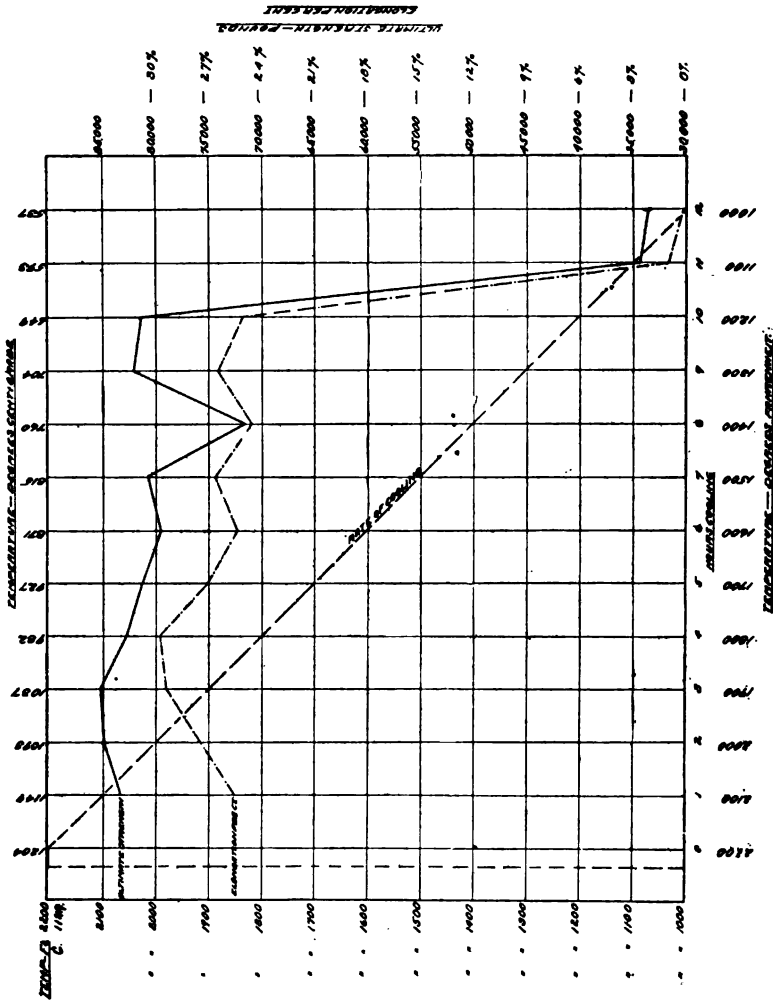


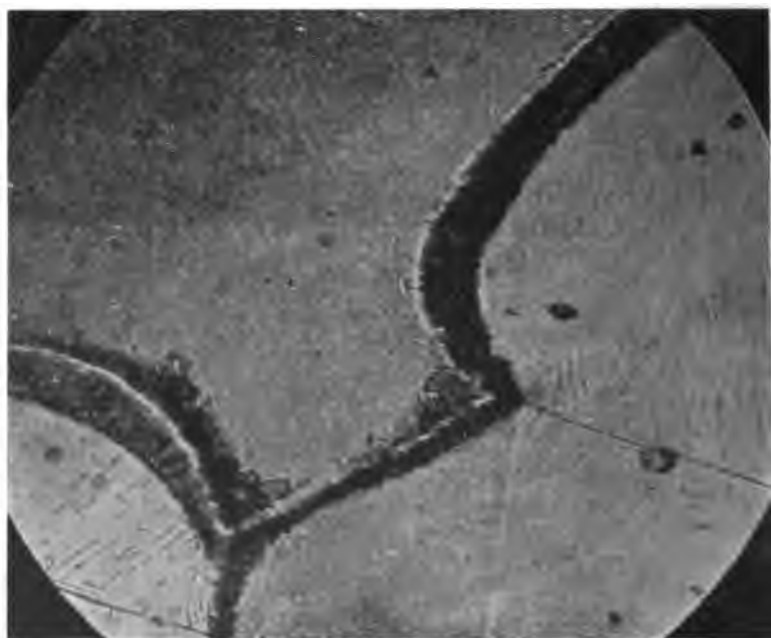
FIG. 13.—(SEE CORRESPONDING TABLE III).
Twelve $\frac{1}{2}$ in. Round Bars heated quickly to 1149° C., held there for 20 min., then cooled at 55° C. per hour, and drawn and water quenched at temperatures noted.

Conclusions as to the Metallography of Manganese Steel

I present the following as fairly well proved points for further observation: In steel containing 10 to 20 per cent. manganese, 1 to 2 per cent. carbon, during cooling, gamma iron begins to freeze at about 1,370° and is for the most part frozen at about 1,270° C.; the eutectic freezes at 1,125° to 1,080° C., or perhaps a little higher temperature with low carbon and manganese mixtures; the mechanical break-up of austenite begins at 850° to 825° C.; carbides separate between the grains at 710° to



Micro. No. 431, Bar No. 11, 540 diam Slight separation.



Micro. No. 430, Bar No. 12, 540 diam. Large carbide separation.
Note twinning.



Micro. No. 434, Bar No. 12, 150 diam. Large carbide separation.

650° C.; the magnetism increases at 550° to 525° C., with further carbide separation between the grains, and there is a further mechanical separation at 430° to 420° C.

In heating, if the steel is originally austenitic, there is a preliminary break-up at 350° C.; a further break-up at 450° to 470° C.; and a complete break-up at 575° C., with separation of magnetic carbides of iron or manganese at 475° and 575° C.

TABLE IV

(See corresponding Fig. 14)

Tensile Tests on $\frac{5}{8}$ in. Round Bars, all Heated to 926° C. Cooled at the Rate of 55° C. per Hour, and Drawn and Quenched at Temperatures Given

Treat- ment No.	Time in Furnace	Quenching Tempera- ture	Elonga- tion, Per Cent.	Breaking Strain, Lb. per Sq. In.	Remarks
1	1 hr.	926	51.6	153,800	No crackle.
2	1 hr. 30 min.	898	56.7	156,700	No crackle.
3	2 hr.	871	61.2	153,950	No crackle.
4	2 hr. 30 min.	843	64.2	153,200	No crackle.
5	3 hr.	816	44.8	137,200	No crackle.
6	3 hr. 30 min.	788	31.0	120,450	No crackle.
7	4 hr.	760	15.1	93,370	No crackle.
8	4 hr. 30 min.	732	15.7	88,750	No crackle.
9	5 hr.	704	10.5	84,120	No crackle.
10	5 hr. 30 min.	676	7.8	78,060	No crackle.
11	6 hr.	649	4.6	73,950	No crackle.
12	6 hr. 30 min.	621	4.5	76,940	No crackle.
13	7 hr.	593	4.5	78,040	No crackle.
14	7 hr. 30 min.	566	3.1	71,220	No crackle.
15	8 hr.	538	2.7	71,625	No crackle.
16	8 hr. 30 min.	510	1.5	68,070	No crackle.
17	9 hr.	482	1.4	74,440	No crackle.
18	9 hr. 30 min.	455	1.5	80,500	No crackle.
19	10 hr.	427	1.2	75,290	No crackle.
20	10 hr. 30 min.	399	0.5	69,570	No crackle.
21	11 hr.	371	0.8	72,500	No crackle.

In rolled steel: Separated carbides begin to be redissolved at about 725° C., and this is completed at 850° to 870° C., with re-formation of austenite.

Slight re-separation of carbides occurs along the grain outlines as the melting point of the eutectic is approached, beginning at about 1,025° C., and continuing to 1,100° C., or over. This is most noticeable in ingot

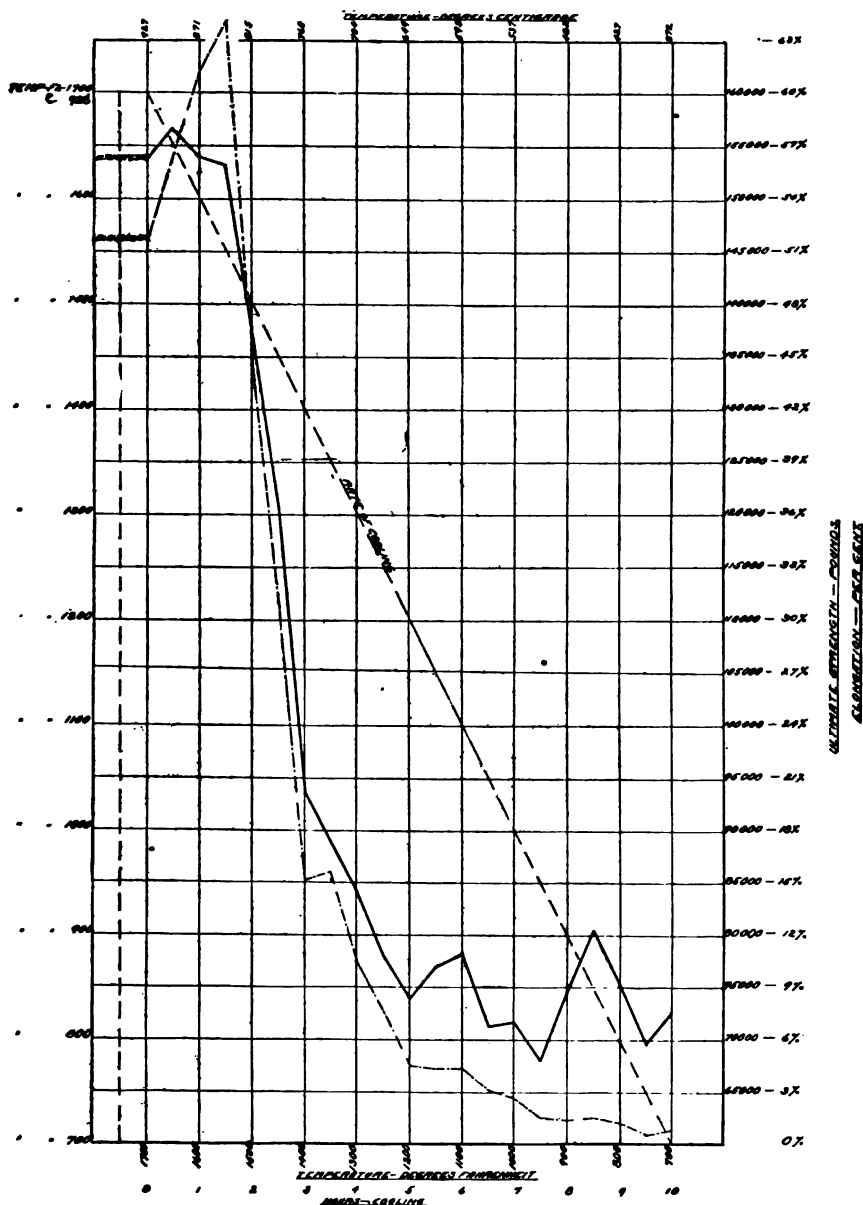


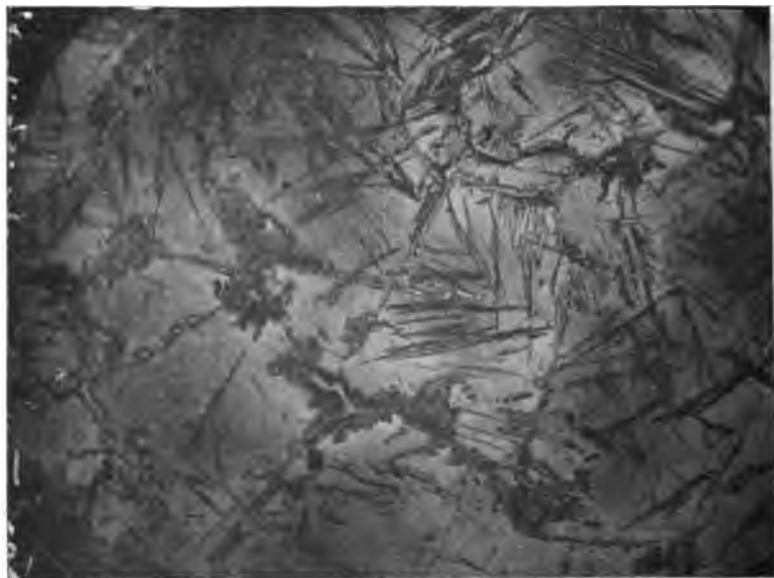
FIG. 14.—(SEE CORRESPONDING TABLE IV).

Twenty-one $\frac{1}{2}$ in. Round Bars heated quickly to 926° C., held there for 30 min., then cooled 100° F. per hour, and drawn and water quenched at temperatures noted.

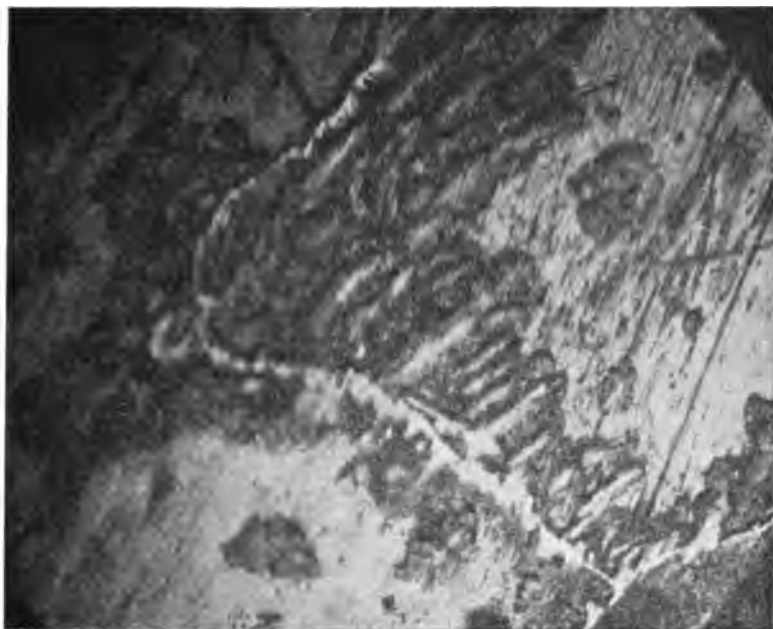
metal, and taken together with the fact that the outlines of the original freezing structures persist in the cast steel at temperatures below $1,125^{\circ}$ C. or thereabout, the remarkable tenderness of ingots between $1,025^{\circ}$ and $1,125^{\circ}$ C. is made clear.

In cast ingot-metal: The melting of the eutectic occurs at $1,120^{\circ}$ to $1,140^{\circ}$ C. if heating is slow, and at about $1,100^{\circ}$ to $1,130^{\circ}$ C. if heating up to this point is rapid; complete resolution of constituents and re-graining with first formation of uniform austenite takes place above $1,150^{\circ}$ C.; cementite re-separates extensively above $1,250^{\circ}$ C.; the mass melts at $1,350^{\circ}$ to $1,375^{\circ}$ C., or lower, depending on its composition.

Structures in Cast Manganese Steel



Micro. No. 466—90 diam. Shows a general view of structures in the interior portion of an ingot about 20 by 20 in. section. Cementite separations within gamma grains. Cementite and lamellar eutectics between gamma grains.



Micro. No. 457—540 diam. Same ingot. Another view of the inter-grain conditions. Eutectic and troostite with ground mass of gamma iron.



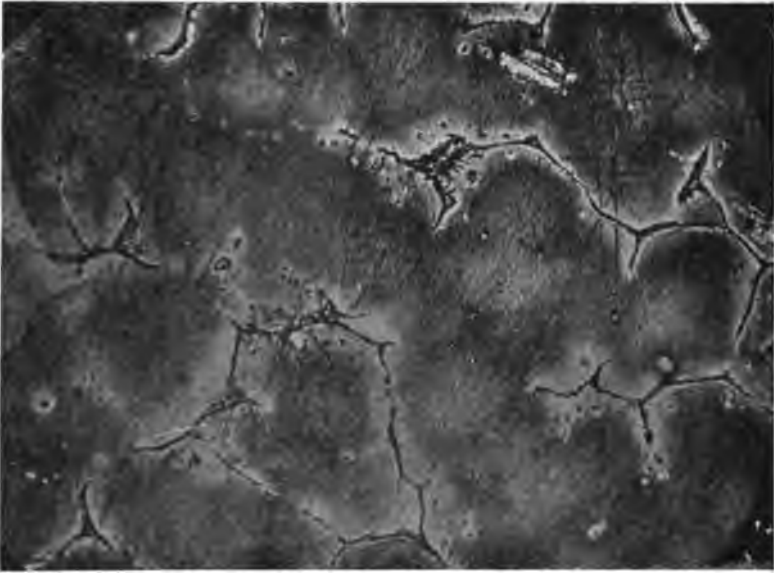
Specimen B. Micro. No. 488—Shows view 150 diameters of same ingot metal after slowly heating to $1,075^{\circ}\text{C.}$, then holding for one hour at $1,075^{\circ}\text{C.}$, then water quenching.



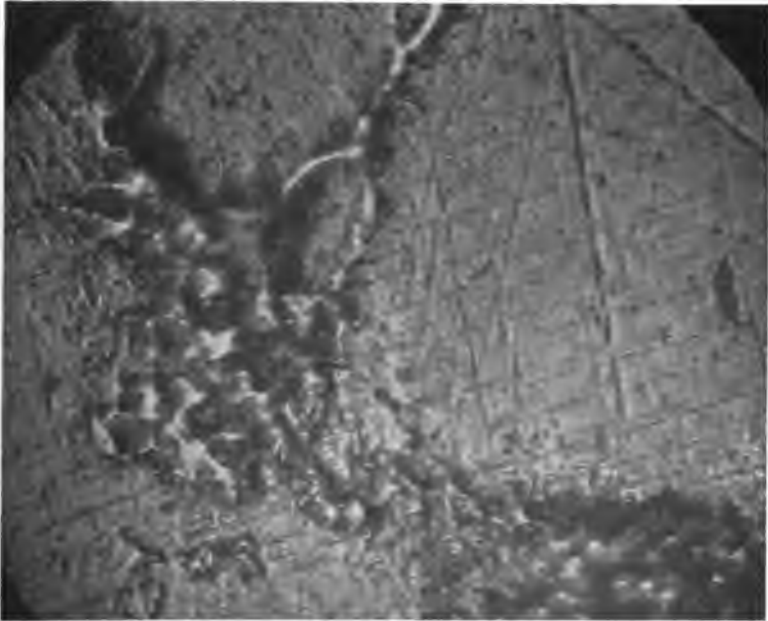
Micro. No. 487—540 diam. Same specimen as No. 488. Inter grain conditions, showing residuals of unabsorbed eutectic.



Specimen C. Micro. No. 515—540 diam. Same ingot as A and B, but reheated to 1,175° C., and held at 1,175° C. for one hour, then water quenched. Uniform austenite with close grain adhesion of reformed grains.

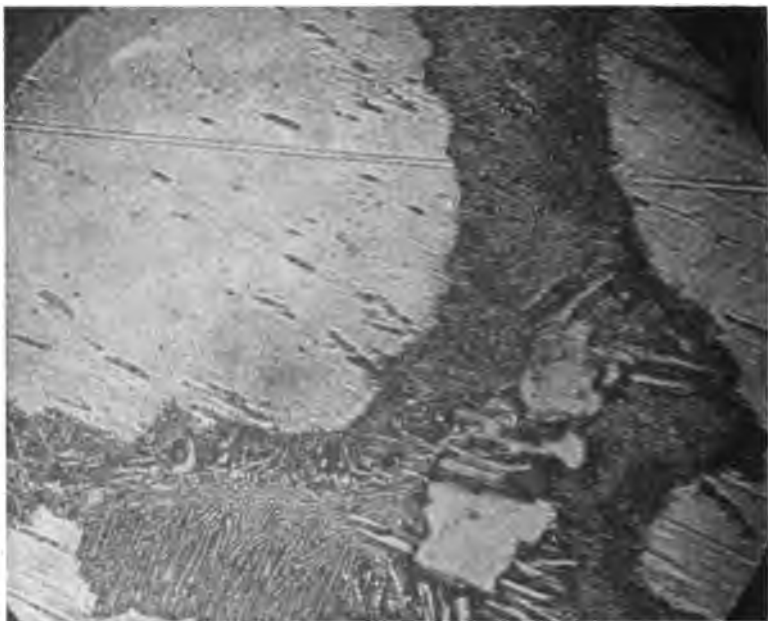


Specimen D. Micro. No. 462—90 diam. Specimen of same ingot as A, B, and C, heated rapidly to $1,250^{\circ}\text{C.}$, and held for one hour at $1,250^{\circ}\text{C.}$ Showing eutectic not absorbed.



Micro. No. 464—540 diam. Ground mass, gamma iron, with unabsorbed amorphous carbides and eutectic.

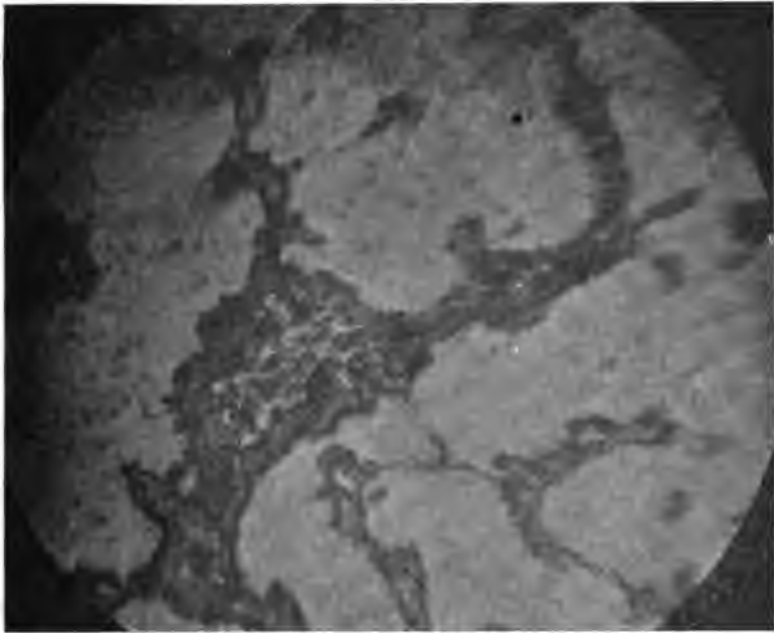
Absorption, that is, resolution, proceeds more slowly at $1,250^{\circ}$ than at $1,175^{\circ}\text{C.}$ for the reason that, at $1,250^{\circ}\text{C.}$ and above, the cementite is separating.



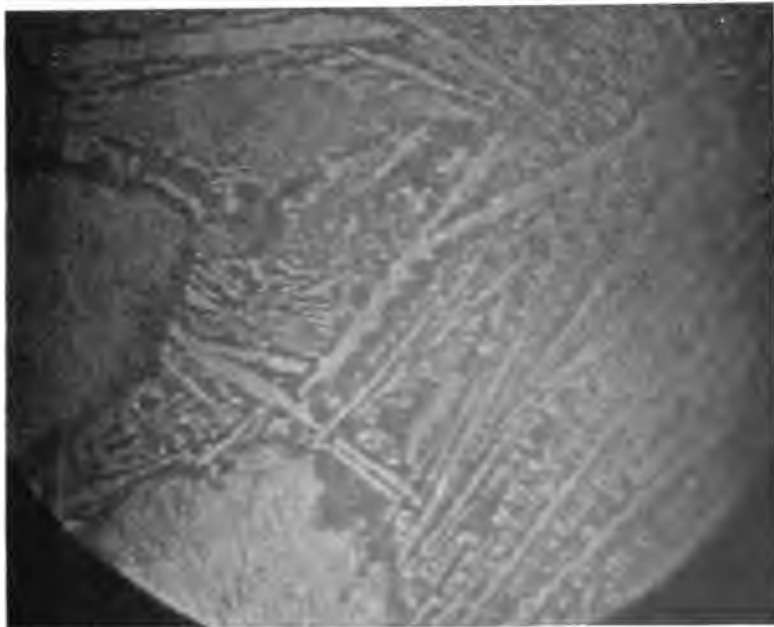
No. 7 Crucible melt. Manganese, 12.54; Carbon, 1.56 per cent. Eutectic percentage higher than in Micro. No. 466. Micro. 485.—Cementite and eutectic of same appearance as noted in manganese-steel ingots of ordinary carbon proportion—a tough, ductile metal.



No. 8 Crucible melt. Manganese, 14.15; Carbon, 1.51; Silicon, 1.05 per cent. Micro. No. 566—540 diam. White and lamellar eutectic with ground mass of gamma iron and no martensite in gamma iron, because the specimen was quenched after cooling from freezing to 1,050° C.—that is just below the eutectic freezing range.

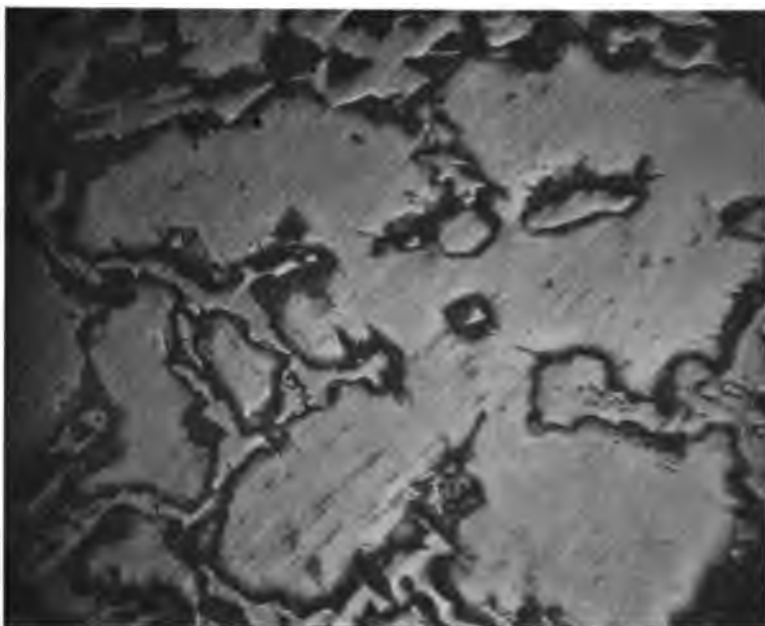


Micro. No. 565—80 diam. High eutectic percentage.



Crucible melt No. 9. Manganese, 30.58; Carbon, 2.05 per cent. Micro. No. 509—540 diam. Coarse partly formed eutectic. Small portions of eutectic not frozen when specimen was water quenched.

This specimen was drawn from furnace after cooling from melting heat to about $1,100^{\circ}\text{C}$. and water quenched. At $1,100^{\circ}\text{C}$., metal was soft and broke in handling, showing that freezing was not complete, thus demonstrating that eutectic freezes within retardation range of $1,125^{\circ}$ to $1,080^{\circ}\text{C}$.



Crucible melt No. 10. Manganese, 26.28; Carbon, 2.38 per cent.

Micro. No. 513—150 diam. Showing ground mass (unknown structure) with large cementite eutectic separation and only small area of a structure not typical lamellar eutectic, lying between ground mass and cementite. A weak, crumbling metal, decidedly not steel.



Micro. No. 514—540 diam. Showing ground mass doubtful, with large areas of cementite eutectic, and a eutectic differing from lamellar eutectic seen in typical manganese steel.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at a meeting of the Institute. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y.

Should the Apex Law be Now Repealed?

BY CHARLES H. SHAMEL, SPRINGFIELD, ILL.

(New York Meeting, February, 1914)

I FEAR most of the Institute members are already weary of the perennial controversy about the apex law. I feel that way about it myself now, though I have been guilty of considerable contribution to the discussion in the past. The discussion does not seem to perceptibly influence previously held views and I would not again break into print on the subject but for the urgent invitation of the Chairman of our Law Committee. This energetic and able member has firmly determined to secure a revision of the mining law and among other things to eliminate the so-called apex provision from the U. S. mining statutes. He is, however, fair about it and has invited me to make "the strongest possible argument in its favor." I am suspicious that he is acting on the psychological principle that it is usually easier to convince an audience against a cause vigorously but unsuccessfully defended than against one wholly mute. Nevertheless, I realize that personally he wishes me no harm, much as he hates the apex law, and so am willing that the Institute have whatever benefit may accrue from my taking up again the unpopular side of the discussion. I say this because the attitude of a large part of our "articulate" membership seems irreconcilably hostile; their minds are made up; favorable consideration is foreclosed; and they become impatient and even sarcastic at any attempt to elucidate a favorable view of the apex law.

The exact question for discussion at the present time is not whether on abstract, or any other considerations, the apex law is the best possible rule, but the very different proposition whether, after nearly 50 years of statutory life and much longer as a practically universal miners' custom, it is now just and expedient to repeal the apex law.

At this point it seems to me that we may profitably devote a paragraph or two to the subject of the origin of law in general, as we are presumed to be considering the subject from the high viewpoint of the general welfare of the nation. The most comprehensive and accurate definition of law in the legal sense is, that *it is the body of rules for the regulation of human conduct which is enforced by the State*, that is, by the nation.¹ Legal

¹ Carter: *Law, Its Origin, etc.*, p. 14.

Dillon: *Laws and Jurisprudence of England and America*, p. 5.

writers have proposed several theories of the origin of law, such as the "Divine Lawgiver" theory; the "Law of Nature" theory; the "Contract" theory (of Rousseau), etc.; but most present writers on the subject maintain that custom is the primary source of almost all law. Thus Mr. Carter, long one of the leaders of the New York bar, says:

"The prime requisite of human society, that without which it cannot subsist, is that each member should know what to expect in the conduct of others, and that fair expectations should not be disappointed. When he knows this, and only when he knows it, he knows how to act himself. This requirement is supplied by conformity to custom. . . . Custom, therefore, is the only law we discover at the beginning of society, or of society when it is first exposed to our observation."

James Bryce, perhaps the ablest writer on English and American constitutional law, says:

"There is, to be sure, a school of juridical writers which does not admit that the people do or can thus make Law, insisting that custom is not Law till the State has in some way expressly recognized it as such. But this view springs from a theory so incompatible with the facts in their natural sense, that a false and unreal color must be put upon these facts in order to make them fall in with it. . . . the ancient doctrine, both of the Romans and of our own forefathers—a doctrine never, till recently disputed—held the contrary."²

Such being the origin of law in general, we are justified in assuming that any law which grew out of a custom—whose legislative or judicial formulation was only the crystallization of previously existent general usage—is the nearest possible expression of the will of the people on that subject. It is of legitimate birth, and is not to be lightly dispossessed of power without conclusive evidence that the conditions and circumstances causing its generation and fostering its growth to the maturity of statutory enactment have materially altered or entirely disappeared. No law can be satisfactory in operation—no law will stand long which is opposed to the will of the people, and in this connection the will of the people of the mining States is the will of the whole people. Though necessarily enacted by our national Congress the mining law only applies in the Western mining States and was made at their solicitation. Their citizens alone are interested in or affected by it and their will (best manifested in custom) alone should control the formation of statutory law on the subject. Laws passed contrary to their desires, through the influence of experts or otherwise, will in them produce dissatisfaction and agitation, leading finally to their repeal. It is noteworthy, in this connection, that it is the influence of the Western mining States which has, up to the present, successfully opposed the frequently recurring proposals for the repeal of the apex law. Let us apply these criteria to our mining law, and to the apex provision thereof, in particular.

² Bryce: *Studies in History and Jurisprudence*, p. 671.

Beyond all question, the whole of the U. S. mining law, including the apex provision, was founded on customs which had prevailed universally for many years in the precious-metal mining regions of the United States—ever since this industry began at the discovery of gold in California. The testimony on this point is conclusive. Justice Field, one of the ablest members of the U. S. Supreme Court, who had lived in California during its early days, says:

"Into these mountains the emigrants in vast numbers penetrated, occupying the ravines, gulches and canyons, and probing the earth in all directions for the precious metals. . . . In every district which they occupied they framed certain rules for their government by which the extent of the ground they could severally hold for mining was designated, their possessory right to such ground secured and enforced, and contests between them either avoided or determined."

Senator Stewart, who had himself taken no insignificant part in the great gold rush of '49, says:

"Upon the discovery of gold in 1848 a large emigration of young men immediately rushed to that modern Ophir. These people, numbering in a few months hundreds of thousands, on arriving at their future home found no laws governing the possession and occupation of mines but the common law of right which Americans alone are educated to administer. They were forced by the very necessity of the case to make laws for themselves. The reason and justice of the laws they formed challenge the admiration of all who investigate them. Each mining district in an area extending over an area of not less than fifty thousand square miles, formed its own rules and adopted its own customs. The similarity of these rules and customs was so great as to attain all the beneficial results of well-digested general laws."⁴

Also Yale, the earliest American writer on mining law, says of the origin of the law and its benefits:

"They reflect the matured wisdom of the practical miners of past ages, and have their foundations, as has been stated, in certain natural laws, easily applied to different situations, and were propagated in the California mines by those who had a practical and traditional knowledge of them in their varied form in the countries of their origin, and were adopted, and no doubt gradually improved and judiciously modified by the Americans."⁵

In the light of such evidence the contrary statements made by some opponents of the apex law are unworthy of consideration, such as:

"Begotten in bland self-complacence by a group of opulent mechanics," and

"What ineffable wisdom is displayed by a government which permits the perpetuation upon its statute books of a law resulting from the nebulous perplexities of a council of day-laborers and village chiefs regarding the occurrence of ore deposits! . . . Are we in America—I ask it in all seriousness—to remain forever the victims of the defecation of the peasant and the mechanic, the hewer of wood and the drawer of water? Are we to continue to accept as truth and rules of conduct the ephemeral ravings of an enriched, illiterate proletariat? What is the law of extralateral rights

³ *Jennison vs. Kirk*, 98 U. S., 453.

⁴ *Congressional Globe*, 1st Session, 39th Congress, p. 3225.

⁵ Quoted in Lindley on Mines, 2d ed., sec. 42.

but the misbegotten conception of untutored laborers assisted by provincial pettifoggers, who set at defiance, and banish from consideration, alike the physical and chemical principles controlling the deposition of ores, and the precedent of centuries of the world's previous mining experiences?"⁶

The apex law, then, having originated in well-settled, universal custom of the mining regions; having been approved at its embodiment in statute law by the sense of right and justice of the ablest men in Congress and among the miners; having been, after six years of trial, re-enacted in a strengthened form without protest, was unquestionably as perfectly adapted to then existing conditions as any human law could be. But there has arisen in later years among the speech-making, periodical-contributing mining men considerable outcry against the apex law. The first question, then, is whether mining and geological conditions have altered to such an extent that the originally wholly satisfactory apex law is no longer adapted to promote the best interests of the mining industry. Unless such a change in conditions has occurred, the alteration of the law to the diametrically opposite policy will be contrary to the clearly manifested and duly enacted will of the people and productive of dissatisfaction, confusion, and injustice.

Of course geological conditions have not changed. They are now and will continue in the future the same as they were 50 years ago. Our knowledge of geological conditions has increased, it is true; but it remains to be seen whether this is a justification for the repeal of the apex law. A very great change has, however, occurred in the financial conditions of mining; and in this I believe we may discover the secret source of the expressed dissatisfaction with the law. In early days, mining was largely carried on by the men who searched out and discovered the ore deposit, or by those who had made fortunes in other mining ventures. Now it is largely controlled by the great financial groups and conducted according to the trust and monopoly methods. Mining has become one of the assets of "Big Business." The complaint against the apex law comes chiefly from this new factor in mining affairs, and its employees and sympathizers. In my own experience among prospectors and such of them as had graduated into mine operators, I do not remember to have heard even one man favor the repeal of the apex law. It is also noteworthy that among the minority who, according to the recently published series of opinions collected by our Law Committee's Chairman, are opposed to the repeal of the apex law are found most of the State bureau officials, and others who presumably reflect the feelings of the actual miner.

The foregoing sociological and juristic considerations, and the opinions of the part of our population actually doing the work of mining and prospecting, are of the utmost importance, and should prevail against the

⁶ Chester W. Purington: *Engineering and Mining Journal*, vol. lxxix, No. 13, p. 622 (Mar. 30, 1905).

opinions of individuals and of comparatively small bodies of specialists largely employed by "Big Business."

But the case for the apex law does not rest alone on such general considerations; and I now pass to a review of its concrete advantages and alleged disadvantages. I can be brief here; for the field has been explored many times already by rival partisans, and its main features—its veins of pay ore and its barren dikes—are known to all of us. The essential feature of the apex law is, that it permits the claim owner having the apex of a vein, lode, or ledge to follow such deposit between certain legally determined vertical planes to any distance, even if he thereby, on a dipping deposit, passes beyond vertical planes through his boundaries. In its favor, it is urged that in plain justice and economic expediency, when a miner has discovered and by his work developed a dipping vein, and worked it on the incline to the vertical plane through his boundary, he should not be stopped by this wholly artificial obstacle, and see another without labor and without price reap the advantage of his discovery and development. Besides its injustice, this would be economically inexpedient; for it would require much more expenditure in dead-work to extract the ore body through two or more shafts than through one. The matter is so plain that amplification and argument are unnecessary. Out of its recognition by practical miners grew the custom which was in due time enacted into statutory law, as I have already shown historically. Unless some disadvantages can be proved against the apex law sufficient to outweigh these considerations, it would be unjust and inexpedient to abrogate this principle and set up the contrary one. Let us therefore examine the disadvantages which are alleged to outweigh the benefits of the law. It is claimed that while the law is "beautiful" in theory, it is in practice "immeasurably bad" because of the difficulty of determining the legal apex, and therefore the ownership of a given ore body; and that by reason of this difficulty an immense amount of tedious, costly and unnecessary litigation has occurred in the past and is likely to occur in the future. The whole case against the apex law rests on these allegations—difficulty of identification and consequent excessive litigation.

Let us first see whether the assertion that the law causes excessive litigation is well-founded. But let us also remember that no law, human or divine, is immune from violation. Are not the fundamental precepts of the ten commandments often broken? A law can only be condemned on this ground when it causes distinctly more litigation than other similar laws. The charge of causing excessive litigation has been brought against the apex law so often that to most persons outside of the legal profession mining litigation is practically synonymous with apex law litigation. If the most unfounded statement is reiterated frequently and forcibly enough, the average person will at last accept it as true. It

occurred to me, while considering this subject, to examine the mining decisions themselves, and ascertain whether, in fact, an undue proportion of such suits arose out of the apex provision. For this purpose, I took the series of decisions collected in Morrison's *Mining Reports*, comprised in 22 volumes, issued from 1883 to 1906. These contain all of the American mining decisions of any importance up to the latter date.⁷

I considered that the most accurate way of arriving at the proportion of apex litigation was to count the total number of syllabuses of all the legal questions contained in all the decisions and compare this with the total number of syllabuses referring to the apex law.⁸

Of course not all mining litigation was carried to the higher courts; but this was a new question for the courts. The apex section itself was brief and indefinite; so that at least an equal, probably a much larger, number of mining cases involving the apex provision were appealed than those involving other provisions. It was during this period, also, that all the important deficiencies of the apex law were supplied by the principles evolved by the courts to make it more definite; so that the proportion of apex litigation is not likely to be underestimated by this method, but rather the contrary.

I confess that I was surprised at the actual figures. The total number of syllabuses in the 22 volumes of decisions is 5,808, of which the number concerning the apex law is 115. The apex cases are only about 1.9 per cent. of the whole.⁹

The apex provision is one of the 28 sections of the U. S. Mining Code as it appears in the Revised Statutes. It occupies 20 lines and the whole code 341; that is to say, the apex section, being longer than the average, constitutes 5.8 per cent. of the whole. Therefore the terrible apex provision causes less than one-third in proportion to its length of the litigation that the other provisions of the mining code do. Instead of

⁷ I did not include the volume recently issued (1912), by the same publishers, beginning a new series, because its plan has been enlarged to include also irrigation and drainage cases and I did not have time to separate the latter from the mining decisions.

⁸ For the benefit of those who are unacquainted with the law reports, which are the repositories of the largest part of existing law in the American and English legal systems, I would say that the text of each decision is nowadays always preceded by an abstract stating briefly the actual different legal propositions decided in the case, arranged in paragraphs, one to each proposition. This is termed the syllabus. Morrison, the editor of the series, is the author of Morrison's *Mining Rights*, well known to all mining men. This is a guarantee that these syllabuses were made or passed upon by some one understanding the mining law and that all the legal propositions contained in the decisions are properly represented in the syllabuses.

⁹ I did not have time to check over the count a second time to be sure of absolute accuracy, but the totals under each heading assembled in the digest of the syllabuses appended to each volume were added on a computing machine; and I am confident that the figures given are substantially correct.

causing 99.9 per cent. of mining litigation, as Dr. Raymond has somewhere stated, it has really caused much less than its proportionate share of the trouble. Facts are stubborn things. The chief, the constantly reiterated, the convincing argument against the apex law is based on a gross mistake as to the facts in the case.

But, some one may say, how could so many men be mistaken for many years about the matter? It is another psychological phenomenon not hard to understand, when examined into attentively, without convicting any one of willful falsehood. The persons making these statements so often that they finally came to be accepted as the truth of the matter, were not lawyers, familiar with the decisions themselves, but engineers and others familiar with the scientific side. Their attention was strongly attracted to the litigation involving the apex law because this turned on geological and scientific facts with which they were familiar. These were the cases reported and discussed in the scientific and mining periodicals. Even when known, the numerous lawsuits turning on other provisions of the law, having little meaning or interest, soon faded from memory and were forgotten, leaving only the clear recollection of the apex litigation standing out from the whole mass of mining litigation, which was dimly realized to be enormous in the aggregate. Further, it was chiefly in the apex litigation scientific men were called in as expert witnesses. The great bulk of mining litigation was carried on without them, and so attracted little attention from them. In this connection also, do not forget that there has always, in all ages and in all lands, been proportionately more litigation in mining than in other industries. As I have said in another place:¹⁰ "The truth is, that from the very nature of the industry of mining for the precious metals, involving more than most others the element of chance—awarding to some rich prizes and to others bitter disappointments only—it is peculiarly subject to bitterly fought litigation. This has been the case in all countries and all times. It long ago attracted the attention of the King of Spain, who, in 1785, in promulgating new mining ordinances for Peru, said:

"The King, convinced of the deteriorated condition in which the important branch of mining of that kingdom has fallen, from a want of method in governing the Reales of mines, and also on account of the frequent and troublesome litigations in which the individuals of this useful profession are involved, causing them enormous expense and distraction from their business by requiring them to reside in the capital and other places where they go in the prosecution of their lawsuits, etc."¹¹

There is nothing in the annals of apex litigation which can equal the litigation lasting in one form or another nearly 50 years about the zinc deposits at Franklin Furnace, N. J., which arose under the identical

¹⁰ Shamel: *Mining, Mineral, and Geological Law*, p. 272¹⁰.

¹¹ Halleck on Mines, p. 589.

common law principle of ownership within vertical planes contended for so strenuously by the opponents of the apex law.¹²

The above considerations, I believe, largely account for the prevalence among engineers of a belief in the existence of excessive apex litigation, but with some there are other less creditable factors operating. One of these is jealousy of the legal profession. Several examples of this attitude cropped out in the recent symposium "Should Our Mining Laws Be Changed," appearing in the *Mining and Engineering World* during the past summer. For instance: "I think that principle was put in the United States law for the benefit of the lawyers rather than for anyone else";¹³ and "Our mining laws appear to benefit the lawyers more than the people in general, or anyone else. . . . extralateral rights benefit lawyers only";¹⁴ and "I believe it was originally implanted in that law with the idea of creating strife. . . and business for certain classes of professional men."¹⁵

As to the probable amount of future litigation liable to arise from the apex law (which is the only question worthy of practical consideration), it should be remembered that during the period of over 40 years that has elapsed since its enactment, its admitted indefiniteness and deficiencies have been almost completely corrected by the decisions of the courts, and there is little likelihood of any notable number of new questions in this connection coming up in the future. I frankly admit that this was not the cheapest or the easiest way of supplying the necessary details; but it has at last been measurably accomplished in that way; and if we now think we can see how this could have been done less expensively, that is no valid reason for rejecting the so costly results, and adopting the contrary policy. I do not deny that there may exist theoretical possibilities of a few new situations arising under the apex law; but I believe the possibility of any important amount of litigation arising on new points is very remote, and wholly insufficient to overcome the weighty considerations against repeal.

An additional exceedingly important consideration against *now* repealing the apex law is that as to all claims already located it would still be in full force and effect. It could very readily happen that a subsequent locator whose own rights were limited by vertical boundary planes would nevertheless be compelled to yield extralateral rights within his boundaries to a prior locator. In fact, the repeal *now* of the apex law would tend to further complicate legal rights and inevitably provoke additional

¹² Any one interested can find this remarkable litigation described with citations to the original decisions in my book, *Mining, Mineral and Geological Law*, p. 41, *et seq.*

¹³ Warren D. Smith: *Mining and Engineering World*, vol. xxxix, No. 4, p. 159, (July 26, 1913).

¹⁴ Murray Innes: *idem*, vol. xxxix, No. 1, p. 22 (July 5, 1913).

¹⁵ E. E. Olcott: *idem*, vol. xxxix, No. 3, p. 112 (July 19, 1913).

litigation, instead of accomplishing its suppression. Outside of Alaska, the jurisdiction of the apex law has been so thoroughly prospected that there is little hope that any important new mining districts will hereafter be discovered; and a change of legal rights in existing districts would unquestionably produce more instead of fewer disputes. These are the strongest considerations which occur to me against the repeal of the apex law at the present date, and, together with other facts detailed above, irresistibly lead me to believe that it would be fundamentally unjust, economically inexpedient and contrary to the best interests of all occupied in mining, except possibly the trusts and monopolies and their satellites, for Congress at this late date in the development of our mineral resources to change the law by eliminating the apex provision therefrom.

With some reluctance, for fear of possibly causing new complications and consequently more litigation, I venture, however, to propose a revision and modification of the apex law, as follows:

1. A restatement of the apex section giving full details for its application to all the different situations of veins or other deposits, boundaries, etc., that have arisen in the past or that may be reasonably likely to arise in the future. This should be based on a careful comparison and codification of the decisions of the courts applied to the different situations. If thus based on existing decisions of the courts, it ought not to cause any increase in litigation, and would enable miners to determine their rights for themselves, and proceed according to law, when the different situations arise in practice. They cannot themselves dig out this information from the court decisions, or even know where to find these. This plan of more definite formulation of the apex law was indorsed by nearly all of those who favored its retention, in the symposium mentioned above.

2. The addition of as complete and accurate definitions as are afforded by the resources of modern economic geology, of the specific kinds of ore bodies to which the apex law should be declared to apply. Merely as a suggestion and a basis for discussion, I would include true fissure veins, shear zones, contact deposits, volcanic necks, and possibly replacement deposits in limestone, as these forms are defined by our former president, Professor Kemp, in his *Treatise on Ore Deposits*, p. 56.

3. As of still greater importance than the matter of definition, I would make the enjoyment of extralateral rights to any subsequently located claim depend on the results of an examination by competent, impartial scientific authorities, instead of a battle of alleged experts in a law court before a jury.¹⁶

¹⁶ I would observe in passing that it seems that much of the disfavor felt by reasonable engineers toward the apex law grows out of their disgust at the performances of many alleged experts during lawsuits involving geological matters. The plan I propose would entirely eliminate this source of honest dissatisfaction, and put the purchasable expert out of business.

4. As a basis for discussion, I would suggest that this scientific authority be the U. S. Geological Survey, which would determine, upon application of the owner, after due notice to adjacent claim owners, whether a given ore body was one to which, by the proposed definitions, extralateral rights legally belonged or not. There should be provision for an appeal under fixed conditions, not to a court, but to a board of higher officials of the Survey, or to some other board of competent and impartial authorities—their decision to be final, and not subject to review by the courts in any manner. Under this plan, the parallel end-line requirement could well be omitted, and the parallel limiting planes for extralateral excavation fixed also by the Geological Survey. This would entirely prevent any litigation about apex questions on claims located hereafter, and at the same time would preserve the justice and all the benefits of the present apex provision. This geological survey should be paid for by the claim owner, and should be allowed to serve as the patent survey, so that expense to the claim owner would not be greater than under the present system.

I am well aware that nothing short of its absolute unconditional repeal will satisfy many opponents of the apex law, and some of them even appear to want to make the repeal retroactive and thereby try to take away extralateral rights from already located claims. But I submit to all reasonable men, that with the modification and revision proposed above, the principle of the apex law should be preserved in our mining laws. I sincerely believe and urge that its unconditional repeal at the present stage in the development of our great mining industry would be ethically unjust and also economically inexpedient; that the introduction now of the opposite policy would inevitably introduce more complications and cause more disputes and litigation, which is the very thing its opponents claim they want to avoid.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at a meeting of the Institute. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y.

Why the Mining Laws Should be Revised

BY HORACE V. WINCHELL, MINNEAPOLIS, MINN.

(New York Meeting, February, 1914)

SCOPE OF DISCUSSION

THE laws here referred to are those which define the status of the prospector for mineral deposits in the soil or beneath it, establish his methods of procedure, protect him in his possession while searching for the subterranean treasures, and give him assurance of title when all required conditions have been fulfilled and valuable minerals discovered.

Regulations for the operation of mines and the safety and health of mine employees are likewise subjects of Federal and State legislation, but are not within the scope of the present program. Various features of our present laws will be discussed in detail by able students of the subject, and specific remedies will be proposed for the most glaring defects. It is my purpose to present in this paper a summary review of the reasons why revision is needed and demanded by the great majority of those in daily contact with the industry.

REASON NUMBER ONE

The first objection to the continuance of the present law is that it was not planned by its framers and the Congress which passed it to apply to many of the kinds of mineral deposits, nor to the mining conditions, which are controlled by it to-day. In 1866, under the title, "An Act granting the right of way to ditch and canal owners over the public lands, and for other purposes," was surreptitiously smuggled into existence our first mining law (14 Stats. at Large, Chap. 262, p. 251). This law provided that "whenever any person or association of persons claim a vein or lode of quartz or other rock in place, bearing gold, silver, cinnabar or copper, having previously occupied and improved the same according to the local customs or rules of miners in the district where the same is situated," etc., a patent might be granted on certain conditions.

This was evidently an Act intended to validate claims already initiated, and to accord Federal recognition to mining locations made in

accordance with the customs and rules of the miners. And the only metals thus provided for were gold, silver, cinnabar, and copper.

In 1872 the substance of our present law was adopted, in an Act amending the Act of 1866, which was enlarged in scope to include all valuable deposits in lands belonging to the United States; although the limitations of the mining industry at that time and the idea in the mind of Congress are clearly shown by the more explicit wording of the Act (now Section 2320 of the Revised Statutes), which specifies "mining claims upon veins or lodes of quartz or other rock in place, bearing gold, silver, cinnabar, lead, tin, copper or other valuable deposits."

Placers had been made in 1870 subject to entry in the same way as lodes, and by various Acts Michigan, Wisconsin, Minnesota, Alabama, Missouri, and Kansas were fortunately excepted from the operation of the mining law, although just why they were so favored remains an interesting question for the student of history.

In 1892 Congress placed deposits of building stone under the placer Act (27 Stats. at Large, p. 348); and in 1897 the same action was taken with reference to petroleum (29 Stats. at Large, p. 526); and still later in 1901 the placer Act was extended to saline lands (31 Stats. at Large, p. 145).

By these various amendments Congress acknowledged that the language of the Act of 1872 in reference to "all valuable mineral deposits" is not to be literally construed; and by passing other special Acts for coal lands has again indicated the incompleteness and insufficiency of the mining Act of 1872. If we now mention the fact that rare earths, phosphates, potash deposits, natural gas, and sulphur are still unprovided for, or locatable under the same conditions as gold and silver lodes or placers, it will be at once apparent either that the law is stretched to-day to cover much for which it was not intended, or that it is in these respects entirely deficient.

Upon closer analysis its inadequacy and unwarranted extension become still more plainly apparent. The Act speaks of "veins or lodes of quartz or other rock, bearing gold, silver," etc., and there is no doubt that only such deposits were in the minds of its framers. The only mines of gold, silver, cinnabar, lead, tin, and copper in operation at that time in those portions of the country to which the law was made applicable were, or were supposed to be, on true veins or lodes; and these lodes had been discovered outcropping above, or lying immediately beneath, the loose surface materials. Only the richer ores were commercially valuable in those days of few railroads and fewer smelters, of primitive metallurgical knowledge and scarcity of technical graduates; and rich ores are the peculiar property of those veins and lodes which most nearly approach the old text-book ideal. Hence the law was naturally drawn to fit such deposits. On this point an eminent authority remarks:

"The author of the mining law had in mind the idea (seldom realized) that mineral veins were always fissures nearly vertical. The force of that observation is of peculiar significance here. From the entire law the conclusion is irresistible that Congress had in mind single distinct fissures, standing almost vertical, and generally thought to be distinct and separate from all neighboring veins, that is, independent of any theory or notion of zones, lodes or broad veins. Moreover, these veins were susceptible of being easily traced upon the surface If the author of the law had been fully informed as to the facts of vein formation as now understood, it is very doubtful whether the law would have been enacted in its present form, and more probable that vertical bounding planes would have been the requirement."¹

Those familiar with mining developments in the West during the past 20 years can instantly appreciate the force of this argument; but since these pages are prepared for many who have not this knowledge, it seems proper to go into greater detail.

Gold and silver ores are still looked upon as typically found in "veins or lodes of quartz." But the most important gold-mining developments at the present moment are in low-grade disseminations through schists and eruptive rocks, such as were never dreamed of by those who framed the law of 1872. Indeed, the Homestake, the Alaska Treadwell, and neighboring properties in Alaska, the majority of the mines at Leadville, the mines of the Kendall district, Montana, and of many other gold and silver districts in the United States, to say nothing of those in other countries, are so different from the deposits for which the law was created that only by a wide stretch of both the law and the imagination have they been brought within its provisions. It is noteworthy, too, in connection with the apex rights which the law purported to grant and which the miners were supposed to favor, that the statutes were not only ignored by miners in the flat veins at Leadville, but so persistently and successfully rejected by all juries before whom mining cases have been considered that it has there become an unwritten law that there are no extralateral rights, no matter what the patents pretend to convey.

Take next the copper mines. How many of those developed within the past 15 years conform to the idea of the law of 1872? Not Ely, nor Bingham (although in both places there are also found true veins), nor Ray, nor Chino, nor Miami. And here again the owners of the mines have found it necessary by mutual agreements to set aside the apex provisions of the law. But my point is here simply that all these great mines present features which place them entirely outside the category of deposits contemplated by Congress at the time the present law was enacted. And if the northern States of the Mississippi basin had not been excepted from the operation of this law, then we might have had the copper-bearing amygdaloids and conglomerates of Michigan, the iron-ore beds of Michigan, Wisconsin, and Minnesota, and the galena-bearing limestone strata of Missouri and Kansas also locatable as mining claims. Indeed, they are

¹ Snyder on Mines, Ed. 1902, vol. i, pp. 661-668.

just as truly veins and lodes as many deposits now being worked in the mining States. What a harvest that would have afforded for mining lawyers and expert witnesses! The entire Mesabi range, 180 miles in length, might have been claimed as a single lode by a very few locators on the outcrop, starting with geologist H. H. Eames, who did actually file mining locations on it at Prairie River falls in 1866. Of course, there has never been an apex suit in Michigan, Wisconsin, or Minnesota. Such a thing is impossible. But there would have been an epidemic of them if wise previous legislation, giving the mineral lands to the States, and wise later legislation, explicitly excepting them from the operation of the Federal law, had not prevented that disaster.

REASON NUMBER TWO

The second objection to the present law is that it discourages prospecting and the discovery and development of new mines. This is, perhaps, the most serious charge that can be brought against it. Indeed, if proved, it is alone sufficient to justify the demand for revision. Traversing again ground already covered in this connection elsewhere, let us for a moment consider the changes that have come about in the West during the past 40 years. In the 60's and 70's there were but imperfect maps; no geological surveys, no published records or data competent as guides for the prospector. The great West was boundless and inexhaustible and mysterious and alluring. It contained mines of wealth untold, and anybody could find one by diligent search. So, with his pick, prospector's pan, and pack train, the pioneer searcher for fortune betook himself into the heart of the wilderness. And wherever some one, luckier, sharper of vision or more industrious than his fellows, chanced upon an outcrop, there he made his location, and to that spot was promptly followed by scores of others. And they, turning over the soil or working the golden gravels or trenching the surface débris, also found outcropping ledges and staked out their locations; and a camp was established. And when so many gathered together in one camp that rules for their conduct were needed, including public recognition of the individual's right to the fruits of his discovery, then a meeting was held, a mining district was organized, and rules were adopted; and these rules had the force of law. The mines were in their infancy, depth had not been attained, and the only definite feature of many a claim was the outcropping lode or "discovery." In that way, and for that reason, a discovery was made the *sine qua non* of a valid location, and this provision, universally adopted by the mining districts, was incorporated into the laws of 1866 and 1872. It worked well for a time. Mines, or at least veins, were easily discovered; and until a prospector had found one he seldom cared to stake a claim. But soon it was found that value attached to quartz locations in the vicinity of good

mines, even without a discovered vein, and many locations were made on barren country rock. Moreover, the land-office officials were complaisant, and had no means for ascertaining the truth or falsity of the affidavits of discovery; and often claims were patented upon a showing of the expenditure of the required amount in development work, although no vein had ever been discovered. As the West became settled and threaded with railroads, two changes of gradual development accomplished results of startling and vital importance to the miner. In the first place, it became exceedingly difficult to find any more outcropping lodes. All the typical quartz veins carrying gold, silver, etc., were located—at least, all those whose “iron hats” compelled attention. No longer could a prospector and his “pardner” with a burro and a two-month grub-stake find half a dozen promising ledges, and sell their locations for a year’s wage. In the second place, Uncle Sam woke up and said the law requires a discovery of valuable mineral in place, and a mining claim is not valid until it is found; and began sending out inspectors and special agents and forestry-bureau employees and others to ascertain the character of these discoveries. And for a time, a good long time too, the prospector was looked upon as an interloper, a rogue, a land thief, who was presumed to be guilty of perjury until he proved his good faith. Unable to stand against these two discouraging obstacles, the increasing difficulty of finding unlocated lodes, and the expense of defending contests brought against him by relays of government agents, the prospector threw up his hands and practically disappeared, either went out of business or moved to some more salubrious clime, where inspectors cease from troubling and the weary none contest.

Lest my statements as to the fundamental necessity for a discovery before the completing of a valid location be questioned, it may be well to quote a few court opinions on that point.

In a recent decision the Supreme Court of the United States uses the following language:

“While the statute does not prescribe what is necessary to constitute a discovery under the mining laws of the United States, it is essential that it give reasonable evidence of the fact either that there is a vein or lode carrying precious minerals, or if it be claimed as placer ground, that it is valuable for such mining, and when there is not enough in what the locator claims to have seen to justify a prudent person in the expenditure of money and labor in exploitation, this court will not overthrow a finding of the lower court that there was no discovery. It is the policy of the Government to favor the development of mines of gold and silver and other minerals, and every facility is afforded for that purpose, but it exacts a faithful compliance with the conditions required. There must be a discovery of mineral and a sufficient exploration of the ground to show this fact beyond question. If the lands contain gold or other valuable deposits in loose earth, sand or gravel, which can be secured with profit, that fact will satisfy the demand of the Government as to the character of the land as placer ground.”²

² *Mining and Scientific Press*, vol. cvii, No. 15, p. 597 (Oct. 11, 1913).

The Supreme Court of the United States in *Erhardt vs. Boaro*, 113 U. S., 527-536, has given us an interpretation of this provision as follows;

"A mere posting of a notice on a ridge of rocks cropping out of the earth or on other ground, that the poster has located thereon a mining claim, without any discovery or knowledge on his part of the existence of metal there, or in its immediate vicinity, would be justly treated as a mere speculative proceeding and would not of itself initiate any right. There must be something beyond a mere guess on the part of the miner to authorize him to make a location which will exclude others from the ground, such as the discovery of the presence of the precious minerals in it, or in such proximity to it as to justify a reasonable belief in their existence. Then protection will be afforded to the locator to make the necessary excavations and prepare the proper certificate for record."

Again in *Chrisman vs. Miller*, 197 U. S., 313-323:

"There must be such a discovery of mineral as gives reasonable evidence of the fact either that there is a vein or lode carrying the precious mineral, or if it be claimed as placer ground, that it is valuable for such mining."

In *Waskey vs. Hammer*, 223 U. S., 85-90, a placer case, the U. S. Supreme Court, on Jan. 22, 1912, held:

"The mining laws . . . make the discovery of mineral 'within the limits of the claim' a prerequisite to the location of a claim, whether lode or placer, the purpose being to reward the discoverer and to prevent the location of land not found to be mineral."

The order of grant is not: Free occupancy for exploration and then minerals if you find them; but is: Free minerals that have been found, and then possession with the right to appropriate them.³ This is conclusively shown by the decision of the U. S. Supreme Court in the case of *Belk vs. Meagher*, 104 U. S., 284, wherein the court said:

"The right to the possession comes only from a valid location. Consequently, if there is no location there can be no possession under it. Location does not necessarily follow from possession, but possession from location."

Upon this point we have the language of former Secretary Fisher, as follows:

"It is becoming increasingly evident that the lode law needs changes in one respect, at least. The law at present does not provide for the creation of any rights in supposedly mineral land, except by the issuance of patents, and in that regard congress has provided that a patent can follow only on a legal location and has said 'but no location of a mining claim shall be made until the discovery of the vein or lode within the limits of the claim located.' As long as congress desires to adhere to the policy at present embodied in statute law of disposing of mineral land absolutely, the law quoted above tends fairly well to the development of mineral properties where the ore can be discovered at or near the surface of the ground, but it seems to be ill calculated for a district where, as is the case notably in some of the copper mining districts, the ore lies at depths of hundreds and sometimes thousands of feet. The expense of actual discovery of the vein or lode within the limits of any particular claim in such cases involves deep exploration, either by drilling or by the sinking of a shaft from

³ G. Mason: *Mining and Scientific Press*, vol. cviii, No. 2, pp. 98 to 100 (Jan. 10, 1914).

the surface, or the extension of a tunnel into the claim. Either of these operations may involve great expense, and it has been repeatedly urged on the department that investors are reluctant to spend the money required without further assurance than the law as it reads at present can give them. On this ground the department has been strenuously pressed to so construe the law as not to require an actual discovery of the lode which is supposed to exist within each claim, but to patent the claims upon evidence of the existence of mineral at or near the surface wholly disconnected with the supposed lodes below and of no value in itself, either present or prospective, it having been further urged that in these cases it was a matter of geological inference that ore bodies did exist far below the surface.

"It is obviously the duty of the department to carry into effect the intention of congress expressed in statutory form. Congress having said that no lode claim should be patented without discovery of the vein or lode, within the limits of the claim, it would be an evident usurpation of power for this department to patent lode mining claims without proof of actual discovery. The frequently repeated assertions that the recent rulings of the department have overturned interpretations placed upon the law for 30 years seem utterly without foundation, as is pointed out in the recent departmental decisions. On the contrary, had the department decided that it could dispense with actual discovery it would have overturned the practically unanimous holdings both of the courts and of the department ever since the enactment of the lode-mining law. Doubtless in some cases claims have been patented where there was little or no proof of actual discovery, but the patenting of such claims is evidently to be laid to a misapprehension of the facts by employees of the land office, and not to a misconstruction of law by the department.

"It seems, however, possible by a change in the law to keep in force the policy of the government expressed in the mining law of rewarding the actual discoverer of valuable veins, while at the same time giving such protection during the work preliminary to actual discovery as would make it possible for capital to invest, taking no more risk than that inherent in the question whether there is or is not in fact valuable mineral in the place where it is sought. I suggest that the law should be amended so as to give a prospector, for a term of years, an exclusive right of possession and of prospecting within a limited area of land. In case actual discovery were made within the time given, patent would issue. The prospector should be obliged to perform a reasonable amount of work during the existence of the permit in order to make evident his good faith in attempting to find mineral within the limits of the claim. He should, however, be given the right by proper proceedings, to settle disputed questions of intervening claims, both in case of conflict with other mineral claims and also cases of conflict with agricultural claimants, so that he might at the earliest possible moment know whether or not his title would be absolutely clear upon his making discovery."

Some of the State courts have carried this discovery requirement to a surprising but perhaps logical extreme. Thus the Supreme Court of Montana holds, in *Butte Consolidated Mining Co. vs. Samuel Barker, Jr.*, 35 Mont., 327, that

"The only way the locator of a quartz lode mining claim can manifest his intention to claim the ground embraced within his boundaries in good faith under the mining laws is by means either of a discovery shaft or a cross-cut sunk or made from an opening upon the claim sought to be located and not upon ground over which he has not complete control as a matter of right or from which he may be excluded at any time at the option of another."

What a contrast this presents to the laws of many countries where

the prospector may search for valuable minerals, even upon privately owned land, and is entitled to work the mines, in some cases sharing with the landlord, and in others merely compensating him for any damages done to the surface. Is our law an encouragement to prospectors?

The discovery of mineral deposits is no longer an incident of a summer vacation. The prospector of the future must possess more expensive equipment, greater technical knowledge, and a larger exchequer, and his operations must perforce be conducted through shafts, tunnels, and drill holes, in some instances taking years of diligent and well-directed effort. The requirement of a discovery before location and antecedent to the granting of any exclusive possessory title is therefore not only irksome and deterrent of results in practice, but wrong in principle.

The laws of most countries recognize the fact that ore deposits are subterranean and in many cases only to be found by digging, and in thus reversing the natural order of things we are conspicuously alone.

REASON NUMBER THREE

The next feature of our present mining law to be criticised is the almost universally condemned "apex" or "extralateral" right by which the miner is allowed to follow his vein beneath the surface of land owned by another. This has been already mentioned incidentally, but merits further special consideration. Its unpopularity is shown by the fact that of the replies in the nature of votes upon this question submitted in response to letters of inquiry sent out by the Committee on Mining Law of the Mining and Metallurgical Society of America, less than 5 per cent. were in favor of its retention. A few expressions of opinion by men competent to bear testimony, published in the *Bulletin of the Mining and Metallurgical Society* and elsewhere, are as follows:

George J. Bancroft.—"I think the extralateral right principle should be done away with."

Robert N. Bell (State Mine Inspector, Boise, Idaho).—"I would advocate the abolition of the abortive extralateral right principle for all future mineral locations. The planes should be vertical and boundaries absolute."

Eliot Blackwelder.—"As to the extralateral rights principle, it seems to me inherently bad. In view of the difficulty of tracing many geological structures underground, and the still greater difficulty of predicting them in advance of actual mine work, I cannot see how this principle can fail to be a fruitful source of dispute and litigation in all but the simplest districts."

Juan Felix Brandes.—"The apex law should be discarded and boundaries made vertical."

R. W. Brightstocke.—"I never had any sympathy for the extralateral rights principle on account of the difficulties in regard to settlement, of which we have had ample records."

R. B. Brinsmade.—"Extralateral rights should be abolished."

R. W. Brock, Director of the Canadian Geological Survey, says: "I do not think

the extralateral principle should be retained. It was tried in Canada and was abandoned."

D. W. Brunton, former President of this Institute and of the American Mining Congress, in his presidential address to the latter uses the following language:

"It is a most unusual thing for a mine to find its way into the producing stage without having to fight one or more 'apex' lawsuits, and all because our legislatures in 1872 gave us the most archaic law that was ever placed on the statute books. No other nation possesses such an antiquated, absurd, and irrational mining law, which, no matter what it was intended to do, has only resulted in a continued expense and annoyance to mine owners and big fees to lawyers and experts. . . . One of the most disastrous effects of this continuous litigation is to frighten capitalists away from mining investments, because observing Eastern investors have learned that the discovery of a new mine carrying rich ore is almost certain to be the beginning of the most expensive and interminable litigation."⁴

Alexander Burrell.—"I am in favor of eliminating the absurd practice of attempting to dispose of dips, spurs and angles for mining claims. There should be no extralateral rights."

Geo. E. Collins, President of the Colorado Scientific Society, says: "The extralateral right principle should be abolished, excepting in areas where it exists already."

W. L. Cumings.—"No extralateral rights in any case should be sanctioned by law."

Thomas L. Darby.—"The extralateral rights principle should not be continued in any future locations of mineral lands."

Algernon Del Mar.—"If the present system of alienation is continued, we should abolish the extralateral rights, and make all mining claims conform to the rectangular boundaries projected vertically downward; but no existing rights should be put in jeopardy."

Francis Drake says: "Every effort should be made to do away with the extralateral rights principle. . . . All boundaries should be vertical."

E. E. Ellis.—"If the present system of alienation of title is retained the system of vertical boundaries to claims should undoubtedly be adopted."

N. H. Emmons says: "Under no condition should the extralateral rights principle be retained in any law of the United States."

J. R. Finlay says: "The principle of granting extralateral rights should be abolished."

H. C. Ferguson, recently of the Mining Bureau of the Philippine Islands, says: "I believe there can be no question that the extralateral right has been a source of endless litigation and uncertainty, and that even if nothing more is done, its abolition would be a great step in advance."

Jno. C. Fleschhutz.—"The extralateral right should be discontinued."

Ernest Le Neve Foster says: "I am utterly opposed to the extralateral rights principle, having been intimately connected with its working since 1872 and intimately mixed as an expert in a large amount of the litigation caused by it in the State of Colorado. Its effect to my mind is that it is a source of litigation, blackmail and quibbling, and often results in unfair verdicts by juries."

R. W. Hadden says: "I do not believe in the extralateral right. It has been the cause of untold litigation, and has caused great hardships both to the original locator on an apex, and a *bona fide* locator of a claim bordering the side lines of the apex claim."

⁴ *Mining and Scientific Press*, vol. cvii, No. 21, p. 815 (Nov. 22, 1913).

H. C. Hoover pithily remarks:⁵ "Lest the Americans think that the apex law was a sin original to themselves, we may mention that it was made use of in Europe a few centuries before Agricola, who will be found to set it forth with great precision."

E. B. Howell says: "I am opposed to the doctrine of extralateral rights. It would be all right if mineral veins maintained their identity and continuity with depth, but they do not, and the inevitable result is litigation."

Murray Innes.—"Extralateral rights benefit lawyers only and should be promptly done away with."

C. E. Jamison.—"It is my opinion, in which I believe the great majority of the people of Wyoming concur, that the present mining laws should be revived somewhat along the following lines:

"(A) Doing away with extralateral rights, although recognizing all rights previously conferred, etc."

Frederic Keffer.—"To abolish one fruitful cause of mining litigation, and to render it possible for the most unlearned man, without the aid of courts or lawyers, to know what was his and what the other man's, I would do away absolutely with the extralateral rights."

J. F. Kemp.—"Practically everyone familiar with the uncertainties and difficulties of the present laws involving apex rights to lode claims, must have a profound conviction of their unsatisfactory nature and must be desirous of seeing future locations made upon a different basis."

Alfred C. Lane.—"The extralateral rights principle should not be retained."

Francis C. Lincoln.—"Extralateral rights should be abolished and vertical side lines substituted."

Henry Louis.—"Mineral concessions should in every case be rectangles of a suitable size, and mineral rights should be bounded by vertical planes; I can see no justification for the law of the apex and extralateral rights."

Hugh F. Marriott.—"In the future all boundaries should be vertical without any exception whatever."

Waller McDermott.—"Extralateral rights are based on a supposed regularity of deposits which does not exist in nature. All the experience of the United States is directly opposed to it in practice; it is unworkable and has had to be dodged by agreements, by local rulings of courts, or by death of litigants."

Philip N. Moore.—"The extralateral rights principle should not be retained in any circumstances."

Henry S. Munroe.—"I believe that the extralateral right should be omitted from all sales of mineral land in the future and that provision should be made for the extinguishment of all existing extralateral rights by condemnation proceedings, even should this require a constitutional amendment, unless such rights are utilized within a definite period of years from the date of the passage of the new law."

E. E. Olcott.—"I should most unequivocally suggest the abandonment of the extralateral rights principle in every possible form it may have assumed heretofore. It has been one of the greatest nuisances in the American mining law, and I believe was originally implanted in that law with the idea of creating strife and friction and business for certain classes of professional men."

R. W. Raymond.—"Apart from the mischievous extralateral right, the greatest cause of confusion and waste in those mining districts of this country which have been afflicted by our mineral land law, has been the lack of public surveys."

M. L. Requa.—"Extralateral rights should be abolished."

L. D. Ricketts.—"I thoroughly believe in giving a right to the mineral only vertically underneath the surface area claimed."

⁵ Translation of Agricola's *De Re Metallica*, p. 83.

F. L. Sizer.—"By all means, the square location, with limiting vertical planes through all lines, should be adopted and the menace of extralateral rights litigation forever disposed of, so far as future grants are concerned."

Geo. Otis Smith, Director of the U. S. Geological Survey, says:⁶ "This law has proven more productive of expensive litigation than of economical mining, and in many of the more recently established and more progressive mining districts has been made inoperative either by common agreement or by compromise between adjoining owners."

Warren D. Smith.—"I think our present mining law in the United States is about as out-of-date and crude an affair as any public statute I have seen. It must have been framed either by farmers or lawyers, as no sane mining man would perpetrate such a thing on an innocent country."

Benjamin B. Thayer.—"The mining claim, instead of being 1,500 ft. in length by 600 ft. in width, shall be 1,500 ft. square, the underground boundaries to be determined by vertical planes projected through the side lines."

R. H. Toll.—"In any case I believe in vertical boundaries."

Arthur H. Wethey.—"The extralateral rights principle has been a most fruitful source of litigation. In future patents it would be well to increase the area of quartz claims and restrict ownership to the mineral beneath the surface."

Montana Society of Engineers, Butte, Mont.—"We would recommend that the area of mining claims be increased, and that the ownership of the mineral be limited by vertical end and side planes."

John E. Hardman.—"To keep the extralateral right any longer in the statute books of the United States would be a crime; in my personal opinion, and in consequence of my Colorado experience, I regard the insertion of the maintenance of the extralateral rights principle a blot on the civilization of the United States and I have no hesitation whatsoever in saying that that feature of the American law should be abolished absolutely and forever."

F. A. Ross.—"But most important of all is the 'square location'—without extralateral rights—by which is removed the most fruitful source of United States mining litigation and its attendant evils."

Maurice Codwell.—"The apex difficulties do not, of course, come up in Mexico, and it would seem that the system followed in that country is better in every way than that demanded by the United States Government."

Kirby Thomas.—"I believe that the Mexican system of locating by *perenenencias*, 100 meters square, with no extralateral rights, is satisfactory, and better than the American system of apex."

J. F. W. Murdoch.—"Not being a lawyer nor a 'mining expert,' I believe that extralateral rights ought to be abolished."

A. Montgomery (State Mining Engineer of Western Australia, Perth, W. A.).—"The lateral rights principle obtaining in portions of the United States is a standing marvel to the rest of the world, and that it could be seriously proposed to perpetuate it outside of cases in which it has unfortunately been already granted seems incredible to most outside engineers with whom I have come in contact."

George W. Riser.—"Elliott Lord says that during the first seven years on the Comstock Lode, twelve leading companies were involved in 245 law suits, nearly all of which were over the right of possession. (Comstock Mining and Miners; *Mono-graph IV*, U. S. Geological Survey, 1883, p. 177). On a smaller scale, every other mining region goes through a similar experience whenever rich ore is found."

Frederick F. Sharpless.—"Vertical boundaries should be adopted and the extralateral rights principle abandoned."

⁶ *Thirty-second Annual Report, U. S. Geological Survey*, p. 15 (1911).

An occasional word is spoken in favor of the apex law. Its supporters are not numerous. They can be divided into three classes: first, those who are not familiar with its working by actual experience, or who speak without careful reflection; second, those who believe that, although it has been the source of trouble and expense in the past, yet there is but little likelihood of such annoyance in the future, that all controverted cases have been litigated and all doubtful questions settled by court decisions, or that the mines have all been found and it is not worth while to make a change at this late day; third, those who are by nature conservative and fearful of any changes, who perhaps recognize the evils of the present, but fear any revision will be for the worse. To these three classes the following remarks are addressed:

(1) It must not be supposed that the parties to apex litigation are the only ones to suffer from it. They pay the immediate and physical costs; and when the bills are presented, they heartily condemn the law which makes such litigation possible. But not all the mines are affected by such trouble all the time, and hope springs eternal, and even the defeated recover their spirits and are sooner or later willing to take another chance. But the fact is that the whole mining industry pays the bill. There is a factor of hazard and loss and expense of uncertain dimensions hanging over every mining investment wherever the apex law is in force. No attorney or mining engineer can safely recommend the purchase of a quartz mine in the West without taking it into consideration. Indeed, the more he knows about mining lawsuits, the larger the factor of safety which he demands on this account. Hence, consciously or unconsciously, the whole business of mining is hampered and forced to carry the burden of this dangerous provision of our present law.

(2) While it is true that the U. S. Supreme Court has handed down decisions which definitely settle some of the principles of apex law, it is very far from true to state that no other vitally important questions remain undetermined. There are points upon which the U. S. Courts of Appeal in different circuits are in direct conflict. There are questions involved in litigation now pending which have never been passed upon by the Supreme Court, and some of these questions contain possibilities which one shudders to contemplate. I may merely mention one as an example. The law provides for the location of mining claims in such a way that the side lines shall be parallel to the outcrop of the discovery vein and not more than 300 ft. distant from it. Many thousands of claims have been located and patented in which the discovery vein crosses the side lines instead of the end lines, and in such cases the courts have decided that the end lines become side lines. Now, in the case of a claim 1,500 ft. in length whose discovery vein crosses the side lines, and whose located side lines therefore become end lines and whose located end lines become side lines, it may be 750 ft. or more from the

apex to the actual side lines. In other words, the patentee, by misrepresenting (innocently perhaps) the relation of his surface lines to the outcrop of his discovery vein, has obtained a patent from the United States Land Office for more land than it was authorized to convey. Is such a title good? Some of our best mining attorneys question it seriously. The question is now before the Federal Court in Utah, and if the decision is against the validity of such patents, the title to valuable claims in every mining camp in the West will at once be shaken.

To the second portion of the second class, those who do not look for the discovery of more mines, we would say that Uncle Sam still controls about 623,000,000 acres of his original farm of less than two billion acres, and that the man who has doubts as to the existence of as many mines upon this remaining one-third as were found upon either of the other one-thirds, must lack confidence in the destiny of the American nation. That the mines have not yet been discovered is no proof of their non-existence; that they are not to be found so easily and rapidly is probably a blessing in disguise, if we once revise our laws so as to make their discovery possible and put their exploitation in harmony with the principles of economy.

(3) With the third class we have to deal in all human affairs. They are typical of the Chinese during the past thousand years, rather than of up-to-date progressive citizens of these United States. Their views are always entitled to a hearing, but when reforms are widely called for, the stand-patter must stand aside or be run down by the chariot of progress.

One rule of the apex law of great importance to the miner in working beneath the surface, and yet one with which the majority of mining engineers do not seem to be familiar, is stated by Judge Lindley as follows:

"In following his vein downward the apex proprietor must keep within it. He cannot crosscut underneath another's surface to reach the vein."⁷

In this respect our apex law is not so good as its German prototype of the sixteenth and seventeenth centuries, which gave to the locator an inclined location with bounding planes parallel to the vein some 25 or 30 ft. from it on both foot- and hanging-walls.

Violations of this rule are frequent, and it is sometimes broken by common consent; but it is occasionally invoked to the great surprise and expense of the miner, who thinks that because the government patent granted him extralateral rights, which he may perchance have still further established by costly court proceedings, he is consequently empowered to crosscut from his own shaft on various levels through his neighbor's ground for the purpose of mining his own vein.⁸

⁷ Lindley on Mines, 2d ed., p. 1111, Sec. 615.

⁸ See *Engineering and Mining Journal*, vol. xcv, No. 17, p. 865 (Apr. 26, 1913).

Other arguments against the apex law will probably be presented in this symposium and other testimony might be procured almost without limit for its condemnation. There can be no question that the sentiment of a large majority of men engaged in actual mining is strongly opposed to its perpetuation in our statutes.

REASON NUMBER FOUR¹

Another defect in our present law to which the attention of Congress has frequently been invited is the lack of any provision for appeals to the courts from the decisions of land-office officials. It is contrary to the general spirit of our institutions and an anomaly in constitutional government to take away from any citizen property rights to which he considers himself justly entitled under the law, by the mere fiat of an appointed government official who is here to-day and gone to-morrow. To place in the hands of such officers the final dicta in matters involving property valued at hundreds of thousands of dollars, and to provide no method of appeal to any duly constituted, permanent, non-political, judicial tribunal, is not only to subject the said officials to severe and unnecessary tests of moral courage and fidelity, but to require in them the qualifications of superior judges and experience in the weighing and interpretation of the law, which many of them cannot be expected to possess. Serious injustice is often done without any remedy at law to the defeated applicant.

The records of the land-office decisions are full of instances of this fact. One of the most recent is what is known as the Yard decision. Four or five years ago the Department of the Interior held that the Land Department might cancel mining claims before application was made for patent, alleging that the discovery is not sufficient, or that the land is held for speculation, or for any other sufficient reason. Now, although it might be claimed that this decision was unjust and *ultra vires*, yet there was no method of taking an appeal to the courts, for they have no jurisdiction over Land Office decisions. In another case, that of J. P. Nichols and Cy Smith, the same question has just arisen, and the former decision is squarely reversed, the present First Assistant Secretary remarking that the decision rendered in 1909 in the Yard case is entirely indefensible, whether viewed from an administrative or a legal standpoint, and that to the extent that such decisions might mislead citizens or officers of the government "into an unwarranted invasion of private rights, it would be repugnant to good administration as subversive of law."²

The Secretary further used the following language:

¹ *Mining and Scientific Press*, vol. cvii, No. 23, p. 879 (Dec. 6, 1913).

"While the title to land remains in the United States, and controversies arise between occupants thereof, whether agricultural or mineral, neither party having invoked the jurisdiction of the land department for the purpose of acquiring the ultimate title, the courts have the power to determine their rights, based upon the law of possession, and all other questions necessarily involved."

The statement of the Secretary, while no doubt strictly accurate as between two mineral locators and so long as the mineral character of the land is not called into question, is with difficulty harmonized by a layman with the language of Mr. Justice Brewer in *Burfenning vs. C., M. & St. P. Ry.*, U. S. Rep. 163, p. 323, as follows:

"It has undoubtedly been affirmed over and over again that in the administration of the public land system of the United States questions of fact are for the consideration and judgment of the Land Department and that its judgment thereon is final. Whether, for instance, a certain tract is swamp land or not, saline land or not, mineral land or not, presents a question of fact not resting on record, dependent on oral testimony; and it cannot be doubted that the decision of the Land Department, one way or the other, in reference to these questions is conclusive and not open to re-litigation in the courts, except in those cases of fraud, etc., which permit any determination to be re-examined."

This instance is only mentioned because of its timeliness and to illustrate my point as to the desirability of giving to some courts the power of review which Justice Brewer says they have not now.

The celebrated Cunningham coal cases in Alaska are another concrete instance of maladministration of justice and the infliction of obloquy and financial loss upon perfectly reputable and law-abiding citizens by the dicta of political appointees, who were forced by the stress of political expediency to render decisions justified by neither the law nor the evidence, and from which there is no recourse. In the interests of justice, provision should be made for appeals in important cases, and perhaps in all cases, from decisions of the Commissioner of the General Land Office or of the Secretary of the Interior to some court of competent standing and jurisdiction, whose decisions could and would be accepted by the public and the interested parties with confidence in their just and correct interpretation of statutes. The enactment of such legislation was specially recommended to Congress in a Presidential message by William H. Taft, but it failed of passage, largely through the misguided opposition of the chief apostle of conservation. It should be brought up again, and insistently, until placed upon our statutes.

REASON NUMBER FIVE

Another very important reform which has been more or less agitated, and is certain to attract the attention of Congress in the near future, is in the coal and petroleum laws. Although of different geological habit and physical structure and mode of treatment, and therefore each

deserving of separate legislation, coal and petroleum are here mentioned together because they are both mineral fuels and both inadequately provided for in existing statutes. Volumes could be written and hours spent in rhapsodizing over our matchless supplies of coal and oil and moralizing over the question of their benefit to that portion of the human race which inhabits the United States of America and its possessions. But such considerations are stayed by the reflection that a ton of coal and a barrel of oil are of no benefit to any one until they are burned, and that coal mines and oil wells are essential to the carrying on of industry, traffic, commerce, and manufacturing as they exist to-day, and that it is for our best economic interest to mine and use every ounce of carbonaceous fuel that can be profitably and efficiently employed in useful endeavor.

The law authorizing the location of coal-land reads as follows:

"Every person above the age of twenty-one years, who is a citizen of the United States, or who has declared his intention to become such, or any association of persons severally qualified as above, shall, upon application to the register of the proper land office, have the right to enter, by legal subdivisions, any quantity of vacant coal-lands of the United States not otherwise appropriated or reserved by competent authority, not exceeding one hundred and sixty acres to such individual person, or three hundred and twenty acres to such association, upon payment to the receiver of not less than ten dollars per acre for such lands, where the same shall be situated more than fifteen miles from any completed railroad, and not less than twenty dollars per acre for such lands as shall be within fifteen miles of such road.

"Any person or association of persons severally qualified, as above provided, who have opened and improved, or shall hereafter open and improve, any coal mine or mines upon the public lands, and shall be in actual possession of the same, shall be entitled to a preference-right of entry, under the preceding section, of the mines so opened and improved: *Provided*, that when any association of not less than four persons, severally qualified as above provided, shall have expended not less than five thousand dollars in working and improving any such mine or mines, such association may enter not exceeding six hundred and forty acres, including such mining improvements.

"The three preceding sections shall be held to authorize only one entry by the same person or association of persons; and no association of persons any member of which shall have taken the benefit of such sections, either as an individual or as a member of any other association, shall enter or hold any other lands under the provisions thereof; and no member of any association which shall have taken the benefit of such sections shall enter or hold any other lands under their provisions."¹⁰

Any mining engineer knows that the development and equipment of a coal mine is an undertaking so expensive that it is not safe to make the outlay needed unless a supply of coal is assured for many years. The limitations placed by the law upon the amount of coal land that may be located by an individual or by an association are therefore either foolish or futile. As a matter of fact, the lack of harmony between the law of Congress and the inflexible law governing economic conditions has led to attempts to evade the former, which have not always been such

¹⁰ Snyder on Mines, vol. ii, pp. 1259, 1260, 1261.

as would pass a creditable examination under the searchlight of modern investigation. The matter is at present in a transitory stage. Coal lands are for sale, in limited areas, under the law, at appraised valuations. The probable solution will be the passage of a bill reserving coal lands from sale, but authorizing the Secretary of the Interior to lease them under terms to fit the conditions in each case, and under the supervision of the Bureau of Mines.

There has been much difference of opinion as to whether petroleum and natural gas are minerals.¹¹ The courts, with few exceptions, have held that these substances are minerals and locatable as such. The Land Department has been on both sides of the question; but the matter is finally set at rest by the Act of Congress which reads as follows: "Any person authorized to enter lands under the mining laws of the United States may enter or obtain patent to lands containing petroleum or other mineral oil, and chiefly valuable therefor, under the provisions of the laws relating to placer and mineral claims." (Act approved Feb. 11, 1897, 29 Stat. at Large, 526.)

Being locatable under the placer Act they are subject to the requirement of a "discovery" before a location can be perfected, and since, as already explained, the law gives no exclusive possessory right to the prospector while he is searching for mineral (except of the spot where he is actually at work, *pedis possessio*) there have been numerous instances where two or more outfits have been drilling on the same tract of land, each trying to make the first strike of oil and thus secure possession, and bloodshed has not infrequently been the outcome of this feature of our senile law. In the interests of peace and for the preservation of oil which might otherwise have been wasted, as well as to protect the Federal land reserves, the oil lands have been withdrawn by Presidential order under the authority of Congress. Legislation is needed, but the situation is not serious, and there is ample time in which to make a thorough study of the entire question and thus prepare to meet conditions undreamt of when the present laws were framed.

REASON NUMBER SIX

There are still other substances which should be provided for, and which were either not known to exist or not considered as valuable minerals in 1872. Among these substances we may mention radium-bearing minerals, phosphates, potash and other salts, rare earths and similar products, all of which are likely to prove of increasing importance and value in the future, and for whose location and exploitation careful provision should be made in our laws.

¹¹ Snyder on Mines, vol. i, p. 284.

The present Secretary of the Interior in his recent report, speaking of this subject, says:

"Some years since this department announced the discovery within the United States of a deposit of potash which it was hoped would render our farmers independent, for a time at least, of all other sources. This deposit still lies unused. No proper laws have been passed by which it can be put into use. A common-sense view of the matter would be to treat these lands as it has been suggested we should treat coal lands.

"So, too, should our vast deposits of phosphate rock be brought into the world's supply. We are giving a constantly increasing volume of thought to the scientific methods by which the fertility of our soils may be increased. And the time is likely to come when the deposited phosphorus in our western lands will be regarded as of almost priceless worth. Few appreciate how extensive these deposits are. They run for hundreds of miles through Wyoming, Utah, Montana and Idaho, and in other States similar deposits of lesser extent are known to exist. We have millions of acres of phosphate lands which are estimated to contain several billion tons of phosphate rock; undoubtedly the world's largest known reserve."¹²

REASON NUMBER SEVEN

From the very first the law has been defective in not requiring notice of mining claims to be filed with the general Land Office or some duly constituted Federal officer. Uncle Sam has been a very careless custodian of the property of his wards.

"Indeed, the United States government does not to-day possess either records or maps showing what portions of its public mineral lands have been appropriated by valid mining-locations, and, being held under possessory title, do not now belong to that domain."¹³

Such carelessness in our national book keeping has led to much confusion and the infliction of unnecessary expense and hardship upon those whom the laws were intended to benefit. Thus, for example, while with one hand the government gave to the prospector the right to those mines which might be found, with the other it handed out land grants to aid in the construction of railroads to the Pacific and thus facilitate the operation of the mines. It said to the railway companies, "You may file your selections with the Commissioner of my Land Office in Washington;" and to the prospector it said, "You may file notice of your mining location with any county clerk. We don't care to be bothered with such details." So the prospector and the railway company filed on the same land, and for years each thought his title unclouded. The prospector spent months of labor and all his cash, and finally sold to a mining company. The railway company sold the land to a lumber company, and spent a million dollars in constructing a road to market the lumber cut by the

¹² *Engineering and Mining Journal*, vol. xcvi, No. 1, p. 29 (Jan. 3, 1914).

¹³ R. W. Raymond: *Discussion of Canadian Mining Law*, by J. M. Clark, *Trans.*, xlii, 617 (1911).

lumber company. Then the government got around to surveying the townships, and the railroad and the mining company both asked for patents, and for the first time was discovered a conflict which had existed for 10 or 15 years, and which never could have arisen if our laws had been good. The mining company said to the railway company, "You have no right to mineral land." The railway company replied, "I only wanted the timber and that was rightfully mine, but I don't believe the land is any good for mining anyhow." Then the government sends the experts of the Geological Survey to investigate and report; and their report is to the effect that general geological conditions are similar to those of some other district where good ore is found, therefore it is mineral land, and must be stricken from the railway company's selections; but, as a matter of fact, there has been no discovery of ore in place as required by the mining law, and therefore it cannot be patented to the mining company. And this is no idle dream, but a picture of situations actually existing under our chaotic mining law.

REASON NUMBER EIGHT

The law at present provides a limit to the time within which patented quartz claims may be attacked for fraud or irregularity of location, but makes no such provision for patented placer claims. Known veins within placer locations must be declared and paid for separately or else they are excepted from the placer patent and can be located by others in lode claims. All veins on placer ground not known to exist at the time application is made for patent belong to the grantee, but without extralateral rights. If an applicant for placer patent can be shown to have had knowledge of the existence of a valuable lode within his lines prior to the making of his patent application, and to have concealed that knowledge, his title as to that vein is subject to cancellation at any time upon the making of proof thereof in court by a contesting locator. There is no limit to the time for such contests, and they are still being brought, in some cases 25 years after placer patent. The law is very defective on this point, for it frequently happens that veins discovered to-day have a value by reason of improved metallurgical processes or transportation facilities which they did not have at the time when the placer claim was located and patented. The owner of such a claim is sometimes put to the expense and annoyance of defending such contests repeatedly, each time at the risk of an adverse verdict, since there is no limit to the number of contestants. The law should provide the same protection for placer as for lode claims in this respect.

REASON NUMBER NINE

The present statutes are defective also in permitting the location of an unlimited number of quartz claims in any district, and in not requiring

actual and useful development. Many promising mining claims and even entire districts have been smothered for years by this practice. Much has been said and written about it, and every old timer knows that the assessment work on thousands of claims which for a quarter of a century have been thus held (and by the other familiar trick of re-location of each other's claims at the end of the year on a sort of community basis), has often amounted to no more work of actual exploration than could be done by a couple of able-bodied single jackers in three months' time. And any one who has bought mining claims in the older camps of the West can testify that he has often paid considerable sums for locations of this sort, although the physical condition of the property was in itself incontestable proof that the claims were at that very moment open to re-location, or could be successfully contested at much less expense.

CONCLUSION

There are many other minor defects in our mining laws; but it is believed that the foregoing presentation of the case will be sufficient to serve as a text for those who feel that something is wrong, but do not know just where the trouble lies. Moreover, if we are unable to convince Congress of the need for revision by showing them the worst of the rottenness, they will hardly be moved to action by fly-specks and an occasional worm-hole. If they desire to legislate in the interest of a large and important industry and by aiding it benefit the entire nation, they will give heed to an appeal from the representatives of that industry. Personally, I believe that the subject is one of great importance and that its proper solution is through the recommendations of a commission appointed by authority of Congress for the study of the entire question and the drafting of a new mining code, after investigation of conditions and the desires of mining men in all parts of the country.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at a meeting of the Institute. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y.

Notes on the Utilization of Coke-Oven and Blast-Furnace Gas for Power Purposes

BY HEINRICH J. FREYN, CHICAGO, ILL.

(New York Meeting February, 1914)

THE American iron and steel manufacturer finds himself to-day barely at the threshold of enormous possibilities for practicing rational economy in the use of fuels. The fuel cost is by no means the smallest of items which enter into the cost of manufacture of iron and steel products, but the great wealth of this country in high-grade fuels, together with a protective tariff, has heretofore made fuel economy relatively unimportant.

In Germany, the use of raw coal for the purposes of iron and steel manufacture has been all but abandoned and large sums of money, formerly irrevocably wasted, are now being saved.

When scanning the literature of this country devoted to the application of gas power, but little information will be found on a subject which, however, is destined to become of considerable importance in the United States, namely, the use of coke-oven gas for the generation of power in gas engines.

This lack of information can be traced to the fact that the regenerative by-product coke oven with its large amount of surplus gas is still far from having attained in this country the universal application which it has found in Europe. This statement needs hardly any corroboration other than the evidence of statistical investigations made by E. W. Parker of the United States Geological Survey, according to which only approximately 25 per cent. of the total coke produced in this country in 1912 was made in by-product coke ovens, whereas 75 per cent. was produced in bee-hive ovens. This entailed the enormous loss of over \$80,000,000 in non-recovered by-products, such as gas, tar, and ammonia, without considering the substantial loss due to the non-recovery of benzol from the coal.

There are two more or less distinct fields of application of the by-product coke oven: one, to furnish as the main product metallurgical coke of specified quality, and surplus coke-oven gas as the by-product, and the other, to carbonize high-volatile coals, and thus produce as the main product large quantities of gas, high in heat value and rich in illuminants, adapted primarily for domestic heating and lighting, while domestic coke becomes the by-product.

Owing to the large tonnage of coke required in metallurgical industries vast quantities of surplus gas become available, for which a field of usefulness must be found. Wherever a steel works is connected with the blast-furnace plant, this surplus gas can advantageously be used in addition to that derived from the surplus blast-furnace gas, in the manufacture and heating of steel, or for the production of power. Thus the necessity of shipping into the plant any other coal except coking coals can be practically eliminated.

With isolated blast-furnace plants which produce their own by-product coke, the uses of the surplus gas are not so obvious, since the quantity of surplus blast-furnace gas by far exceeds the immediate demand for power. But where blast furnaces are grouped in the vicinity of large cities, they will have a better opportunity than ever for profitably selling their surplus gases for domestic heating and lighting, or in the form of electric power, because they can furnish these commodities at lower cost than the cities themselves could produce them.

The modern by-product coke oven is fully capable of producing excellent metallurgical coke for blast-furnace use, from certain coals and coal mixtures, and, in addition, a quantity of surplus gas commensurate in every way with coal and water gas, and of a heating value equal to modern specifications for illuminating gas. By the proper selection of coking coals, the blast-furnace manager is thus placed in the enviable position of manufacturing blast-furnace coke, satisfactory to *himself*, in coke ovens operated under *his* own management, and yet of furnishing all, or at least the rich portion of, his surplus coke-oven gas for distribution through the city gas mains.

But a large field of opportunity remains to apply profitably the surplus gases of metallurgical industries for the purposes of neighboring communities, even in the steadily-diminishing instances where the obsolete minimum-candle-power specification is still maintained, and where public service corporations prefer to install by-product gas chamber ovens of their own for the purpose of carbonizing gas coals and disposing of the total coke-oven gas for illuminating purposes. Modern industrial life causes the demand for electric light and power to increase by leaps and bounds, so that public service corporations are constantly obliged to add to the capacity of their electric light and power plants. The purchase by such corporations of electric current generated from industrial surplus gases at nearby blast furnaces and coke-oven plants, or the acquisition of these surplus gases for power production in power plants of their own, becomes a very desirable transaction, which offers financial advantage to both seller and buyer, and ultimately to the consuming public at large.

By taking advantage of the recent innovation of H. A. Brassert, blast furnaces are now able to insure fulfillment of a contract for the delivery of

a specified uniform amount of power in times of business depression as well as activity. Brassert virtually transforms a non-active blast furnace into a huge gas producer, and gasifies in it, small coke, raw coal, and coke breeze, on the principle of the slagging type of producer, using open-hearth slag as flux. This has been very successfully demonstrated at South Chicago and Gary.

This disposes of the argument that curtailment of pig iron and coke production in time of business depression militates against the fulfillment of a contract of this nature.

In order to show what can be accomplished in the practical utilization of the surplus gases of a blast furnace and coke-oven plant of moderate size, calculations are appended, which were based on the following assumptions:

Two isolated blast furnaces, of 350 or 450 tons daily capacity each, are installed near a large city, together with a coke-oven plant of just sufficient size to furnish the necessary coke for these blast furnaces. Coking coals of proper quality for making good blast-furnace coke can be delivered for \$3 per long ton f.o.b. the furnace plant. The by-product coke is charged to the blast furnaces at \$4.25 per net ton, which price is about \$1.25 below the cost of standard beehive coke delivered in that locality. Coke-oven gas of a heating value of 550 B.t.u. per cubic foot, but not subject to minimum-candle-power specifications, can be used in the city for domestic purposes and would bring a price of 12 c. per 1,000 cu. ft. The prevailing cost of electric power is 1.2 c. per kilowatt-hour distributed. With a practically unlimited power market, the total surplus from the blast-furnace and coke-oven gases of this plant can be absorbed by the established electric power company, which operates steam turbine power stations of approximately 300,000,000 kw-hr. total output per year generated at a yearly use factor of about 38 per cent.

With such favorable local conditions, the total quantity of coke-oven gas can be used for domestic or power purposes, or both. To realize this, gas from some outside source must be used for under-firing at the coke ovens. Blast-furnace gas should not be used for this purpose in this instance, since this ideal gas-engine fuel can much more profitably be utilized for the production of electric power. Producer gas made from small coke and coke breeze in revolving grate or slagging type gas producers would answer splendidly and should be used if sufficient quantities of these fuels are available. As a general rule, however, the amount of coke breeze does not exceed 7 per cent. to 8 per cent. of the total coke made, and this quantity is not sufficient to produce the necessary gas for under-firing.

In this discussion, it was assumed that a mixture of raw coal and coke breeze is gasified in some type of mechanically-stirred gas producer equipped with apparatus for the recovery of by-products. This producer

plant would be in operation at practically full output at all times, making this method of providing for under-firing very cheap and attractive. The question whether the total quantity of coke-oven gas produced should be marketed for community use, or only its rich portion, while the lean portion is used for power purposes in the natural state, or in admixture with blast-furnace gas, can be properly answered only when the quality of the coking coals is known and when the value of the coke-oven gas is correctly appraised. This value depends entirely upon the use to which the gas is put. It is determined from case to case by the price of other fuels which could be used for the same purposes and which this gas replaces.

Distinction must be made between the "cost of production" and the "value at consumption" of such gases, because different gases vary considerably in pyrometric effect and the heating value per cubic foot of any gas compared with that of another fuel is not necessarily a criterion of its intrinsic value. For example, if blast-furnace gas and coke-oven gas are used for power purposes, their value can be determined as follows:

A blast-furnace gas-engine power plant of about 16,000 kw. installed capacity, operating at a use factor

Total kilowatt-hours produced per year

Maximum continuous rating of plant $\times 8,760 = 36$ per cent.

would produce about 50,000,000 kw-hr. per year.

The cost of producing electric current at the switchboard, based upon the values given in the author's recent paper published in the Year-book for 1913 of the American Iron and Steel Institute, would be about as follows:

	CENTS
Net operating expenses including gas purification per kilowatt-hour...	0.15
Fixed charges 15 per cent. on the total investment of \$1,440,000 (\$90 per kilowatt installed capacity).....	0.43
The total cost of power per kilowatt-hour without fuel expenses would thus be.....	0.58
If electric power distributed in the locality is worth 1.2 c. per kilowatt-hour and if the value of power delivered at the switchboard of existing steam power plants is.....	0.80
(deducting 0.40 c. per kilowatt-hour distribution charges) then the value of fuel per kilowatt-hour consumed in the gas engine station would be $0.80 - 0.58 =$	0.22
Assuming a heat consumption of 19,000 B.t.u. per kilowatt-hour (over-all thermal efficiency 18 per cent. at 36 per cent. use factor) and a heating value of blast-furnace gas of 100 B.t.u. per cubic foot, the gas consumption per kilowatt-hour would be 190 cu. ft., valued at 0.22 c.	
The value (not the cost) of 1,000 cu. ft. of purified blast-furnace gas would, therefore, in this particular case be $\frac{1,000}{190} \times 0.22 =$	1.16
On the basis of equivalent, absolute heat units and disregarding the difference in pyrometric effect (which is of little influence in gas-engine work) the value of coke-oven gas of 550 B.t.u. per cubic foot compared with that of blast-furnace gas of 100 B.t.u. per cubic foot would be $5.5 \times 1.16 =$ (per M cu. ft.).....	6.4

If, however, the use factor of this power plant were materially greater, for instance 80 per cent., as it could be in case of parallel operation of the gas-engine plant with existing steam-turbine installations, then the value of coke-oven gas used in gas engines would be much higher.

At 80 per cent. use factor, a 16,000-kw. power plant would produce about 112,000,000 kw. hr. annually and the cost of generation at the switchboard would be as follows:

Net operating expenses including gas purification per kilowatt-hour...	CENTS 0.09
Fixed charges: 15 per cent. on \$1,440,000.....	0.19

Total cost per kilowatt-hour without fuel expenses.....	0.28
If the value of power at the switchboard of existing steam-turbine stations is.....	0.80
as before, and if the heat consumption of the gas engines is 16,000 B.t.u. per kilowatt-hour (over-all thermal efficiency 21.5 per cent. at 80 per cent. use factor) and the heating value of blast-furnace gas 100 B.t.u. per cubic foot, then the gas consumption per kilowatt-hour would be 160 cu. ft. valued at 0.80—0.28 =	0.52
The value (not the cost) of 1,000 cu. ft. of blast-furnace gas would now be $\frac{1,000}{600} \times 0.52 =$	3.25
and that of coke-oven gas on the basis of equivalent heat units 5.5 $\times 3.25$ or approximately (per M cu. ft.).....	18.0

The cost of sulphur purification of the coke-oven gas must be deducted, since this expenditure reduces the profit realizable from its utilization. But, since an equal amount would have to be subtracted from the selling price of illuminating gas, because sulphur cleaning is just as essential in one case as in the other, the values found above can be directly compared with the price obtainable by the sale of this gas for illuminating purposes.

It will be seen that the intrinsic value of these gases depends greatly upon the use factor of the power plant, and that, at a price of 12 c. per 1,000 cu. ft. for domestic gas, coke-oven gas would really be more valuable as a gas-engine fuel if the power plant operates at 80 per cent. load factor throughout the year.

From this calculation the deduction could be made that, in case of an unlimited market for electric power and with nearly full output of the gas-engine station, it would be more profitable to operate gas engines on coke-oven gas than to sell the latter for domestic purposes. This conclusion would be perfectly justified if coke-oven gas could be used in very large gas-engine units just as satisfactorily as blast-furnace gas. In spite of the present remarkable development of the gas engine, such is, however, not quite the case. Especially in this country, there are but very few coke-oven gas engines of medium size in operation and these were built a number of years ago when even the blast-furnace gas engine in this country was, as it were, in its infancy.

The blast-furnace gas engine has to-day attained a very high standard, as can readily be seen by the truly remarkable results achieved with the

world's largest gas-engine plant at Gary; but the coke-oven gas engine, although mechanically equivalent to the blast-furnace gas engine, has to deal with a fuel of entirely different character.

Blast-furnace gas contains on an average not more than $3\frac{1}{2}$ per cent. hydrogen, from 25 per cent. to 28 per cent. carbon monoxide, and has but a fraction of 1 per cent. of methane; its heating value is about 95 to 100 B.t.u. per cubic foot. Coke-oven gas, on the other hand, varies greatly in composition according to the kind of coal carbonized and the time of generation during the process of carbonization. It contains from 50 per cent. to 60 per cent. hydrogen, 4 per cent. to 8 per cent. carbon monoxide, 2 per cent. to 5 per cent. illuminants and from 28 per cent. to 35 per cent. methane and its heating value ranges from 450 to 650 B.t.u. per cubic foot. Blast-furnace gas requires approximately its own volume of air, while coke-oven gas must be mixed with from 8 to 15 volumes of air for complete combustion and satisfactory operation in gas engines. The large percentage of hydrogen in coke-oven gas causes an extremely rapid flame propagation, so that the time of combustion of a mixture of coke-oven gas and air is considerably shorter, and this combustion much more of an explosive character, than is the case with blast-furnace gas. The compression in coke-oven gas engines must, on account of these characteristic qualities of the fuel, be kept considerably lower than is customary and appropriate for blast-furnace gas engines.

The principal reason for the early difficulty with coke-oven gas engines abroad was that high compression pressures were used, which resulted in excessive explosion pressures. The latter not only caused serious damage to gas cylinders, pistons, and piston rods, but were responsible for extremely unsatisfactory engine operation on account of severe premature explosions, which occurred particularly at heavy loads. Costly experience has taught European gas-engine manufacturers to reduce the compression pressure in coke-oven gas engines to 110, and even to 85 lb. per square inch, depending somewhat on the percentage of hydrogen in the gas. While, according to thermodynamic laws, a lower compression pressure is necessarily followed by a lower thermal efficiency, it has been found in practice in Germany that the actual heat consumption per b.h.p. hour of coke-oven gas engines at full load is practically the same as that of blast-furnace gas engines for the same load condition. Theory and practice thus seemingly disagree, but the explanation of this phenomenon is not difficult: one reason is the better mechanical efficiency at lower compression, but the principal reason is that coke-oven gas engines must, for practical considerations, be operated on very lean gas mixtures, that is, with a large air excess. The presence of a much larger quantity of air than is theoretically necessary, and the rapidity of flame propagation, result in perfect combustion of the charge at practically constant volume,

while blast-furnace gas-engine indicator cards frequently reveal after-burning of the mixture during expansion.

Owing to the snappy action of the gas, coke-oven gas engines are at times quite susceptible to back-firing and premature explosions. Effective cooling of gas cylinders, pistons, piston rods, etc., becomes, therefore, a very important matter on account of the intense heating of these parts. The absolute quantities of coke-oven gas consumed during one working cycle are comparatively small, even at full load, and perfect regulation of coke-oven gas engines is, therefore, not as easily accomplished as that of blast-furnace gas engines. Serious difficulties were encountered in the earlier days because it was found quite impossible to maintain satisfactory parallel operation, especially at fractional loads, of coke-oven gas-engine generators feeding into the same system. Ignorance on the designer's part was very largely responsible for these difficulties, because gas ports and gas-valve areas were made far too large, and entirely out of proportion to the size of the air ports, since no attention was paid to the low specific gravity of coke-oven gas. Much larger quantities of gas than actually required at any specific load were thus caused to enter the gas cylinders, and these earlier engines nearly always operated on excessively rich mixtures. The obvious result was, after burning, destruction of exhaust valves, piston rods, and cylinders, violent back-fires and vicious premature explosions, all of which caused extremely unsatisfactory commercial operation.

These difficulties can be readily overcome at present by correct application of a few simple laws and experiences on the designer's part. To-day the coke-oven gas engine has reached such a high state of perfection in Germany that it is second only to the blast-furnace gas engine in importance and serviceableness, with the qualification, however, that unit capacity and more particularly the rating must be conservative.

Several years ago it was thought perfectly admissible to rate coke-oven gas engines a good deal higher than blast-furnace gas engines, and it was reasoned that the higher heating value of coke-oven gas should allow of higher mean effective pressures in the gas cylinders. When it was found, however, that, after a comparatively short time of operation, these engines began to show distinct signs of distress, and caused an appalling amount of difficulties and expense, designers and operators wisely reduced the maximum capacity by strictly limiting the mean effective pressure to about 65 lb. per square inch. When it was clearly realized that coke-oven gas engines must under no circumstances be rated higher than blast-furnace gas engines, that the compression pressure should be lowered and lean mixtures must be used, the operation of plants which formerly were distinguished by their endless troubles, improved as soon as the necessary changes had been made. Several large coke-oven gas-engine stations in

Germany have now been in very successful, continuous operation for over five years.

The latest coke-oven gas engines built by Thyssen & Co., of Muelheim-Ruhr, Germany, were installed at the Bonifacius colliery, in Westphalia. Each engine is of the twin tandem double-acting four-cycle type having four gas cylinders $47\frac{1}{2}$ in. in diameter, 51 in. stroke, and develops at 94 rev. per minute about 5,000 b.h.p. Alternating current of 5,000 volts is generated and used at the various pits for operating electric hoists and other machinery. The power station can be operated in parallel with the R.W.E. in Essen, and is tied in with the blast-furnace gas-engine station at Gelsenkirchen and with several steam-turbine plants in the vicinity. Parallel operation is beyond criticism and the load factor of these engines is very high—from 90 per cent. to 100 per cent.—since peak loads are taken up by the blast-furnace gas-engine plant and the steam turbines. These engines were built two years ago and are probably the largest coke-oven gas engines in the world. Previous experiences with smaller gas engines were carefully considered when these engines were designed. The compression pressure is only 85 lb. and the maximum explosion pressure does not exceed 250 lb. per square inch. Each cylinder end is provided with three igniters. The gas consumption as measured by means of a large gas holder was found to be 12,000 B.t.u. per killo-watt-hour at 90 to 100 per cent. load. The over-all mechanical efficiency, including generator, is 82.3 per cent. at that load. The engines are equipped with butterfly valve gear, and regulation is performed on the combination "quality-quantity" principle. In the opinion of Thyssen & Co., even larger coke-oven gas engines than these could be built without difficulty. The repair costs of such engines would not be any higher than those for blast-furnace gas engines, provided they receive equally efficient care.

The Friedrich-Wilhelms-Huette of Muelheim-Ruhr, Germany, have equipped with their gas engines what they contend is the largest coke-oven gas-engine plant in the world. The power house at the Prinz Regent colliery has a total capacity of 21,600 b.h.p. and contains four d. a. twin tandem gas engines of 4,000 b.h.p. each, one d. a. single tandem unit of 2,000 b.h.p. and two d. a. single tandem units of 1,800 b.h.p. This firm is now building an air compressor direct coupled with a two-cylinder twin coke-oven gas engine of 1,700 i.h.p. capacity, furnishing 8,750 cu. ft. of free air per minute compressed to 85 lb. per square inch, which is used for various purposes about the coal mines.

Ehrhardt & Sehmer, Saarbruecken, Germany, are among the foremost builders of gas engines in Europe. The largest coke-oven gas engines built by this firm have four cylinders $47\frac{1}{2}$ in. in diameter, $45\frac{1}{2}$ in. stroke, and operate at 108 rev. per minute, giving 4,600 b.h.p. This firm claims to be prepared to build such engines in unit sizes of

8,000, and even 9,000 b.h.p., if such large engines were demanded, and now has under construction a unit 51 in. in diameter, 51 in. stroke, to operate on "Mond" producer gas, which in the mixture unit contains more hydrogen than coke-oven gas.

M. A. N. of Nuernberg, Germany, who were the first gas-engine builders to introduce the double-acting four-cycle gas engine in its present form, claim that they are building units of 6,000 b.h.p. capacity in four cylinders. This concern has probably the largest number of gas engines in operation throughout the world.

There are not many coke-oven gas engines of such large unit capacity in operation in Europe, and it seems that about 1,100 to 1,200 b.h.p. per double-acting gas cylinder is at present the upper limit of such engines abroad.

The overwhelming majority of gas-engine manufacturers in this country restrict the capacity of coke-oven gas engines to about 700 or 850 b.h.p. per double-acting cylinder at present and until more experience is available, which will undoubtedly be the basis for a gradual development considerably beyond the present maximum unit size. This prudent and conservative policy on the part of American gas-engine builders shows excellent judgment, and deserves warm appreciation and cordial support, because it will surely forestall troubles and disappointments. The coke-producing industries should encourage this spirit and assist the manufacturers by installing coke-oven gas engines and developing a field which has lain idle altogether too long. Ultimately the producer of electric power, using coke-oven gas engines, will be the beneficiary if he is the benefactor now.

The questions of design and material for gas cylinders and of the best system of regulation and valve gear arrangement were very thoroughly and ably discussed in a paper presented by Prof. Paul Langer of Aachen, Germany, before the recent annual meeting of the American Society of Mechanical Engineers. Professor Langer's conclusions are based on both theoretical and practical considerations and coincide with the present views of the majority of gas-engine manufacturers abroad. Careful study of this paper will prove highly interesting and instructive to those concerned in the subject. Briefly, Professor Langer advocates the continued use of cast-iron gas cylinders, preferably in one piece, and he recommends the so-called combination, "quality-quantity" regulation method, which is so easily and perfectly secured by the universal use of simple butterfly valves for gas and air control.

Turning now from the mechanical features of the coke-oven gas engine to the fuel itself, it should be remembered that the presence of sulphur in coke-oven gas in the form of sulphuretted hydrogen and carbon bisulphide was the cause of very serious troubles before it was learned how to combat its influence. The slightest water leak in the gas cylinders

from defective pistons or water-cooled exhaust valves resulted in serious corrosion of all finished parts, and particularly of piston rings, piston rods, and metallic packing. This corrosion was caused by sulphuric acid formed by the combination with oxygen and water of sulphur dioxide, resulting from the combustion of sulphur in the gas. Instead of striking at the root of the evil by proper sulphur purification, and by prevention of water leaks, attempt was made to cure the trouble by resorting to building materials which would not be attacked by sulphuric acid. The author remembers that the first single-acting coke-oven gas engine designed by him in 1901 was equipped with gas-cylinder liners and exhaust valves made of a special phosphor bronze.

Later, several gas-engine builders in Germany abandoned the use of water-cooled exhaust valves and substituted solid, non-cooled valves, in order to reduce the liability of water leaks. This practice is now well established for blast-furnace gas engines, but the most prominent and experienced manufacturers prefer to use water-cooled Durana metal exhaust valves for coke-oven gas engines on account of the much higher temperature of the exhaust gases. The true remedy was found, however, when it was learned to design pistons, cylinder heads, and gas cylinders in such a manner that cracking of these parts was avoided. But, even now, it is one of the most important duties of the operators to watch carefully for water leaks and, fortunately, the presence of water in the gas cylinders can easily be discovered by the dull black appearance of the piston rods.

The corroding influence of sulphuric acid formed by sulphur in the gas in the presence of water can often be seen on the exhaust piping whenever water has to be injected to muffle the noise of the exhaust. In several plants abroad aluminum exhaust pipes which are not attacked by acids were tried with very good success, but the prohibitive cost of the material makes its extensive use impracticable. Cast-iron pipes and mufflers with a 2-in. coating of concrete or lead-lined pipes are used in several plants and in a few exceptional cases the short cast-iron pipe connections between exhaust chambers and mufflers are simply replaced every second or third year.

Considerable progress has been made in recent years in designing sulphur cleaning plants which eliminate nearly all of the sulphuretted hydrogen, although no practical means has so far been discovered to separate carbon bisulphide from the gas. Gas-engine manufacturers in Europe are, however, willing to guarantee satisfactory and continuous operation of gas engines supplied with purified coke-oven gas containing as much as 1.25 grains of sulphur compounds in 1 cu. ft. The sulphur purification is accomplished by passing the coke-oven gas, after recovering the by-products, through filter boxes consisting of a number of sections filled with iron oxides or with a mixture of iron ore and certain

patented masses. A mat which is much used in Belgium with considerable success consists of two-thirds bog iron ore and one-third patented "Lux" mass which has the following composition:

Fe_2O_3	72.40
Al_2O_3	8.00
SiO_2	2.60
CaO	1.40
Na_2O	2.90
Na_2CO_3	5.00
H_2O	8.13
	100.43

The mat is regenerated from time to time by removal from the purifiers after a certain length of service and exposure to the atmosphere, or else continuously by adding to the gas 2 to 3 per cent. of air, which is drawn in at a convenient point between the coke-oven batteries and exhausters.

Nitric acid formed in the gas cylinders during combustion of the charge has a corroding effect upon the finished engine parts similar to that of sulphuric acid. Nitric acid is formed from the traces of ammonia remaining in the gas, after passing through the by-product plant. The danger from nitric acid is minimized if the direct ammonia process is used, since, by the latter, the ammonia is recovered from the gas so completely that hardly any trace remains.

Naphthalene, which is deposited by the gas particularly in cold weather, easily obstructs pipe lines and valves. This also has been the cause of much annoyance. If benzol is recovered from the gas no trouble from naphthalene deposits can occur, since it is absolutely necessary for efficient benzol recovery to extract the naphthalene from the gas. In plants where benzol is not recovered, it happens not infrequently that the gas pipes, etc., have to be steamed out from time to time in order to dissolve the naphthalene, which otherwise accumulates in the piping and on the valves, until the output of the power plant is noticeably reduced. It should be mentioned incidentally that benzol recovery, in connection with by-product coke-oven plants, improves gas-engine operation owing to the elimination of certain hydrocarbons, and because the heating value of the gas is reduced about 5 per cent. Back-firing and premature explosions occur much less frequently when debenzolized coke-oven gas is used in gas engines, as practical experience in a large coke-oven gas-engine plant in Germany has shown. Coke-oven gas used for power purposes, or as fuel in a steel plant, does not require any illuminating properties; the recovery of the benzol from the gas for sale offers very attractive financial possibilities and yields an exceptionally handsome profit on the investment.

A straight-forward acknowledgment of the salient difficulties with earlier coke-oven gas engines coupled with a full account of the remedies which eliminated the trouble in subsequent installations can have only a beneficial effect upon the cause of the coke-oven gas engine. We learn mostly by our mistakes, but if warning is freely given and also properly heeded, the repetition of failures can and will be avoided in the future. The meager experiences had with one or two earlier coke-oven gas-engine installations in this country are, in the author's judgment, not sufficient premises to argue for or against the use of coke-oven gas for gas-engine purposes and to draw conclusions of any value. The evident hesitancy on the part of the great majority of gas-engine users in this country to adopt the coke-oven gas engine as part of their standard power equipment is based upon lack of knowledge rather than upon discouraging facts. Just as the producer-gas engine is unjustly being blamed for the shortcomings of certain gas producer installations of the past, so the reputation of the coke-oven gas engine is still suffering from the effects of former ignorance of the peculiarities of a gas-engine fuel which has many ideal qualities but requires intelligent handling.

Coke-oven gas engines are now used abroad to no small extent, but their application has so far been more or less limited to the generation of electric power. The principal reason is that European, and particularly German, coke-oven plants are usually located at the coal mines, where no demand for other forms of power exists. In a few instances coke-oven gas blowing engines share in the blowing of blast furnaces, but only with a view to insuring the safety of the furnace plant in case the supply of air delivered by the blast-furnace gas blowing engines should, for some reason, suddenly fail. In these very rare cases, the coke-oven gas engine is merely a rather unnecessary factor of safety, which can readily be dispensed with in modern blast-furnace plants. The application of the coke-oven gas engine for direct driving of rolling mills is to the author's knowledge not illustrated by a single installation abroad or in this country. No inherent difficulty peculiar to the coke-oven gas engine is responsible for this condition; in fact many considerations point clearly to the advisability of its use for this purpose. Its absence from this field is largely explained by the geographical separation of coke-oven plants and rolling mills.

The load conditions of rod, wire, and sheet mills are not unfavorable for direct gas-engine drives, since they impose upon the prime mover neither violent nor excessive load variations. The average power demand of such mills is moderate, so that frequently single tandem gas-engine units are fully capable of performing the work. The rope wheel, which usually drives a number of stands, is necessarily of large diameter and can easily be given sufficient weight to provide for ample flywheel effect.

Uniformity of rotation is thus insured and it is not difficult to obtain a perfectly uniform product. The direct-connected rolling-mill gas engine for light continuous mills does not require much overload capacity, and can therefore be suitably rated to operate at a high load factor. The gas consumption is then very low and the thermal efficiency high. The result is a substantial fuel economy per ton of finished product, compared with steam-engine, steam-turbine, or electric-motor drives.

The principal advantage of direct gas-engine mill drives is, of course, the saving in cost of installation and operation. Such direct drives do away with costly combinations of electric central station, transformers, transmission lines, mill motors, and the requisite expensive auxiliaries. They are, moreover, not attended by the multiplicity of efficiency losses on account of the roundabout way of generation, transformation, and transmission of energy, which are handicapping electric mill drives. Blast-furnace gas engines are used for light rolling mill purposes in a number of steel plants abroad and they have proved the adaptability and serviceableness of the gas engine for driving direct-connected roll trains in years of satisfactory service.

In our country the installation of by-product coke-oven plants located near blast furnaces and steel mills is rapidly becoming distinctly American practice. The use of coke-oven gas, or of a suitable mixture of blast-furnace and coke-oven gas, in gas engines for rolling-mill purposes has, therefore, a better future here than abroad.

Blast-furnace gas of low heating value and great volume does not lend itself readily to economical long-distance transportation through pipe lines, because the first cost of compressor equipment and pipe line would alone be prohibitive. Besides there would be the high maintenance and operating expenses of such an arrangement. For coke-oven gas containing from five to six times the amount of heat energy in a given volume, these conditions are much more favorable. The transmission of coke-oven gas for illuminating purposes through distances of 80 and 90 miles is not unknown in this country, and the expenses incidental to the installation and operation of booster stations are moderate. Similar conditions obtain in the case of piping a mixture of blast-furnace gas and coke-oven gas, although, of course, in a less degree. In this country, large steel plants are frequently so extensive, and cover so much ground, that the distance from the blast furnaces to the light rolling mills is considerable. Sometimes these mills are operated under different management, or even by independent corporations. The use of coke-oven gas, and the installation of direct-connected gas engines for driving these mills, may, in such instances, offer both financial and operating advantages. Manifestly, no general rule can be laid down which would apply in all cases where the question of direct gas-engine drives for rolling mills is at issue. Local

conditions of load, of arrangement of mills, of distance from the source of gas supply, and others, must be carefully considered, and the intrinsic value of the gas for this particular purpose must be determined from case to case, in order to realize the greatest possible returns from its utilization, whether inside or outside of the steel plant. Each single case must, therefore, be examined on its own merits, and the influences must be intelligently weighed, which individually and collectively bear upon the financial result of such installations.

No matter what objections could justly or unjustly be raised against the use of coke-oven gas for direct power generation in modern gas engines, none of these can possibly apply to the use of a mixture of blast-furnace and coke-oven gas. The practice of combining blast furnaces, steel mills, and coke-oven plants in one locality gives the American iron and steel master an enormous advantage over the majority of his European competitors in the matter of rational utilization of the available surplus gases. It is evident what truly ideal conditions would obtain in such combined plants if only one kind of gas fuel were used for all requirements of the plant. A gas mixture in suitable proportions of blast-furnace and coke-oven gas would fulfill the most exacting specifications which could be imposed. It could be used to heat the blast for the blast furnaces, to operate blast-furnace and Bessemer gas-blowing engines, to produce electricity in gas electric central stations, to run the pumping plant, to serve as bench fuel at the coke ovens, to heat the pig-iron mixers, to produce steel in open-hearth furnaces, to heat the ingots in the soaking pits, and the steel in the reheating furnaces, to drive gas engines direct connected to certain roll trains, to supply the needs of the foundry, and, finally, to raise steam in boilers. Such a gas mixture would offer these steel plants even greater advantages than those enjoyed by a few others in this country which are still blessed with an adequate supply of natural gas.

The scope of this paper does not permit discussion of the metallurgical uses of gas fuels, and reference should be had to Emile Houbaer's recent paper on this subject which was read before the (British) Iron and Steel Institute's October meeting at Brussels. Houbaer's exceedingly valuable contribution to the knowledge of the application of blast-furnace, coke-oven, and producer gas for steel-making purposes illustrates particularly recent achievements at the works of the John Cockerill Co., of Seraing, Belgium, which has truly been the pioneer in the economic utilization of industrial surplus gases in its different phases.

It was pointed out in previous paragraphs that both blast-furnace gas and coke-oven gas possess certain characteristic qualities which are advantageous or disadvantageous from the standpoint of gas-engine operation. The use of a mixture of these gases very happily combines the good points of both, while it eliminates nearly all their objectionable

features. The addition of a small portion of coke-oven gas to a much larger quantity of blast-furnace gas results in a moderate increase of both heating value and ignition velocity of the gas-engine fuel mixture. With a suitable compression pressure perfectly satisfactory results from the use of such mixtures in gas engines are assured. The amounts of hydrogen and hydrocarbons are materially smaller than in coke-oven gas, but somewhat greater than in blast-furnace gas, so that this mixture in composition and effect is somewhat similar to air-blown producer gas. A segregation of hydrogen will not occur if the mixing of the constituent gases is thorough, and if the gas holder is designed to prevent pocketing and stagnation of the gas mixture, which is not a difficult matter. The first requirement can be very easily accomplished by scrubbing both gases simultaneously in regular static and dynamic gas washers, which are necessary for cleaning blast-furnace gas for engine purposes. The so-called secondary gas washers of the centrifugal type, whether fans, disintegrators, or Theisen washers, produce such a thorough and uniform mixture of the gases that segregation of the elements of low specific gravity cannot occur in the short time of travel of the gas mixture from the gas-washing plant to the place of consumption.

There would not be any difficulty in maintaining a heating value of the gas mixture to all intents and purposes uniform, if this task were committed to the action of automatic devices. One, or, if necessary, several, automatic recording gas calorimeters—for instance, of the "Smith" type—could be equipped with a maximum-minimum electric-contact attachment, corresponding to the permissible maximum and minimum heating value of the gas mixture. These calorimeters would control—by means of relays and electric motors—gate or butterfly valves, arranged in the coke-oven gas pipe at, or near, the point of connection with the blast-furnace gas main.

The suggestion of using a gas mixture for gas-engine purposes is by no means new or original, with the exception perhaps of the proposed method of controlling the heating value automatically. Gas-engine plants using such mixtures have been in very successful operation abroad for a number of years. Owing to intelligent design and to simple butterfly valve gear regulation, variations of considerable magnitude in the heating value of the gas mixture are apparently without detrimental effect upon the operation of these engines. The heating value of the mixture is controlled by hand at these plants. A mixture of one part of coke-oven gas of 500 B.t.u. and of 15 parts of blast-furnace gas of 100 B.t.u. would have a heating value of 125 B.t.u. per cubic foot.

Let us assume that the chemical composition by volume of the two original gases in some particular case is as follows:

Blast-Furnace Gas, Per Cent.		Average Coke-Oven Gas, Per Cent.	
CO.....	26.0	CO.....	7.5
CO ₂	12.7	CO ₂	2.0
H.....	3.0	H.....	51.0
CH ₄	0.3	CH ₄	29.5
C _n H _m	0.0	C _n H _m	2.0
N.....	58.0	N.....	8.0
	100.0		100.0
B.t.u.	101	B.t.u.	500

If one part of coke-oven gas is mixed with fifteen parts of blast-furnace gas, the chemical composition of the resulting mixture would be approximately the following:

1 : 15 Coke-Oven Gas : Furnace Gas Mixture	
CO.....	24.8 per cent.
CO ₂	12.0
H.....	6.0
CH ₄	2.1
C _n H _m	0.1
N.....	55.0
	100.0 per cent.
B.t.u.	125

The composition of this gas mixture corresponds very nearly to that of producer gas made from coke or anthracite coal, as will be seen from the low content of hydrogen and hydrocarbons, etc. A gas mixture of this typical composition would make an ideal gas-engine fuel. A gas-engine plant of much larger capacity could be installed and operated, owing to the increase in quantity, and the improvement in quality, of the available gas fuel. The argument that the admixture of valuable coke-oven gas to blast-furnace gas would be uneconomical, on account of the unavoidable losses caused by large quantities of gas escaping unused at times of light load, is justified only if the load factor of the power station is very low. This will not be the case, however, if the gas-engine station is operated in parallel with existing steam power plants. When carrying the bulk of the average load in the gas-engine station, leaving peak loads to be taken care of by the steam turbo-generators, these gas losses would be of very little importance.

If such arrangements are made with the public service corporation operating steam power plants in the district, the largest possible gas-engine power station should be installed, limited in capacity only by the average constant hourly power demand and, of course, by the amount of available surplus gas mixture. Spare units in the gas-engine station are unnecessary, since a number of existing steam turbo-generators would stand by in case part of the gas power plant were, for any reason, temporarily disabled. The maximum capacity of the gas-engine power station should not be restricted too much by applying an excessive arbitrary "safety factor"

in determining what portion of the total available surplus gas should be depended upon for power generation. The fact that the gas mixture is supplied by two practically independent sources constitutes in itself a safety factor of no little value. At times of momentary shortage of either ingredient the regular output of electric power would be maintained by admitting to the engines a mixture leaner or richer than standard. The possibility of using in the engines, producer gas made by one of the existing blast furnaces operating according to Brassert's gas-producer principle, as mentioned elsewhere, is an adequate safeguard against the influence of a curtailment of pig iron and consequently blast-furnace gas production brought about by a business slump. Blast-furnace producer gas has about the same heating value as the gas mixture and its composition by volume is approximately as follows:

Blast-Furnace Producer Gas

CO.....	34.0 per cent.
CO ₂	1.6
H.....	2.9
CH ₄	1.0
B.t.u.....	126

The percentage of hydrogen in furnace producer gas is considerably smaller than in the standard gas mixture. The former gas can, therefore, be substituted for the mixture with impunity. The higher percentage of carbon monoxide in the producer gas will counterbalance the reduction in hydrogen to a large extent, as far as the effect upon gas-engine operation is concerned. It can thus be expected that the change from one gas to the other can be made even without important readjustments of valve and damper setting on the gas engines.

Conditions could arise during a blast-furnace campaign which may necessitate the temporary curtailing of gas production of one or both furnaces. Delays caused by casting, changing tuyères, and minor repairs, requiring generally but a few minutes, are harmless for the gas-engine power plant if, following common practice, a gas holder of sufficient capacity is installed. As far as the question of relining the blast furnaces is concerned, this necessity occurs but once in three or four years and requires from one to two months. Both blast furnaces would of course never be relined simultaneously, so that one furnace would always be available to operate as a gas producer. The quantity of gas made by the producer furnace is ample to generate all the power which a mixture of blast-furnace gas from two iron-producing blast furnaces and of the required amount of coke-oven gas could produce in times of normal business conditions.

The proper choice of the "safety factor" of surplus gas utilization, to which allusion was made, is entirely a matter of local conditions and of

good judgment. In the case under discussion the highest possible factor of safety was chosen to prove the point in question.

Whatever the capacity of the gas-engine plant is, both gas-blowing and electric engines should be equipped with exhaust-heat boilers. Steam of any desired gauge pressure can be generated in such boilers at very small cost, and over 50 per cent. of the heat ordinarily rejected in the exhaust can be recovered. The steam can be utilized in many ways: for heating purposes, for operating steam turbo-generators, or for blowing gas producers, especially if by-product recovery gas producers are installed in connection with the coke-oven plant. Practical experience in a number of European gas-power plants shows that about 1.8 lb. of steam of 150 lb. gauge pressure can be raised in this manner for each brake horse power developed in gas engines operating at full load. This quantity increases to about 2 lb. per brake horse power if the gas engines operate at approximately half load. It will be shown later that the requirements of about 1.5 lb. of steam per pound of coal gasified in the by-product recovery gas-producer plant are fully covered by the amount of steam raised by exhaust-heat boilers in the gas-engine station contemplated in this instance.

Before giving comparative detailed calculations to prove the financial advantage of using a mixture of blast-furnace and coke-oven gas instead of straight blast-furnace gas for power generation in a gas-engine plant, a few points regarding the cost of the fuels entering into this calculation have to be discussed.

It is very difficult to determine the actual cost of generating blast-furnace gas and it is therefore customary to appraise this gas on the basis of the value in heat of an equivalent quantity of coal. In the present instance coal of 13,500 B.t.u. per pound costs \$3 per long ton and 1,000,000 B.t.u. are worth $\frac{1,000,000 \times 300}{13,500 \times 2,240} = 10$ c. Blast-furnace gas from merchant furnaces having a coke consumption of about 2,400 lb. per ton of foundry iron contains about 101 B.t.u. per cubic foot; 1,000 cu. ft. of this gas are therefore worth $\frac{1,000 \times 101}{1,000,000} \times 10 = 1.01$ c.

Coke-oven gas of 550 B.t.u. appraised on the same basis is worth $\frac{1,000 \times 550}{1,000,000} \times 10 = 5.5$ c. per 1,000 cu. ft. It was shown that the intrinsic value of this gas varies according to the method of utilization. For high-temperature work, such as reverberatory furnaces or the like, the appreciation due to the higher pyrometric effect amounts to approximately 35 per cent., so that its value for these purposes becomes 7.5 c. per 1,000 cu. ft. and the value of 1,000,000 B.t.u. increases to 13.5 c. This fact is of considerable importance in the matter of selection of the most economical bench-fuel for the coke-oven plant. A little calculation will readily show the point in question:

If producer gas generated in a by-product recovery gas-producer plant were used for under-firing, there would be required $\frac{1,150}{135} = 8.5$ cu. ft. of this gas per pound of coal, assuming that 1,150 B.t.u. are necessary to carbonize 1 lb. of coal, and that the by-product producer gas has a heating value of 135 B.t.u. per cubic foot. A coke-oven plant producing 1,000 tons of coke per day at a yield of 75 per cent. of coke from coal carbonizes approximately 2,700,000 lb. of coal in 24 hr., requiring about 23,000,000 cu. ft. of by-product producer gas. Assuming that one short ton of coal generates 125,000 cu. ft. of gas, there would have to be gasified 185 short tons of coal per day. The cost of making this gas would be as follows:

1. Charges per year:

(a) Fixed charges at \$1,600 investment in the complete plant, per ton of coal gasified, figuring on 6 per cent. interest, 5 per cent. amortization, and 1 per cent. for taxes and insurance, or a total of 12 per cent., =

$$0.12 \times 1,600 \times 185 = \text{\$35,600.00}$$

$$(b) \text{ Coal: } 185 \times \frac{2,000}{2,240} \times 3 \times 365 = \text{\$180,000.00}$$

It is assumed that the necessary steam for producer operation is generated free of charge, in exhaust-heat boilers attached to the gas engines, so that no expenditure for steam coal has to be considered.

(c) Conversion Cost: This includes all labor, materials, supplies, repairs, gas purification, acid and bags for sulphate of ammonia, etc., and amounts approximately to \$1 per short ton of coal, or:

$$185 \times 1 \times 365 = \text{\$67,500.00}$$

The total charges per annum are, therefore, \\$283,100.00

2. Credits: Coal containing about 1.4 per cent. of nitrogen yields about 70 lb. of sulphate of ammonia and 7 gal. of tar per short ton of coal gasified. At a market price of \$60 per ton of sulphate and 2.5 c. per gallon of tar, the net returns per annum are:

$$(d) \text{ From sulphate of ammonia: } 70 \times 185 \times 365 \times 0.03 = \text{\$142,000.00}$$

$$\text{From tar: } 7 \times 185 \times 365 \times 0.025 = \text{\$11,800.00}$$

The total yearly credits (without gas) are thus \\$153,800.00

The net cost of by-product producer gas is, therefore:

$$\text{\$283,100} - \text{\$153,800} = \text{\$129,300.00}$$

The total quantity of coal gasified per year is $185 \times 365 = 67,500$ tons, giving about 8,500,000 M cu. ft. of gas.

The cost per 1,000 cu. ft. is therefore $\frac{129,300.00}{8,500,000} =$ approximately 1.5 c.

If this gas has a heating value of 135 B.t.u. per cubic foot, the cost of 1,000,000 B.t.u. is $\frac{1,000,000}{1,000 \times 135} \times 1.5 = 11.1$ c.

Comparing the value of coke-oven gas with the cost of by-product producer gas on a B.t.u. basis, it will be seen that it is a matter of economy to use producer gas for bench fuel at the coke ovens, if coke-oven gas can be utilized to better advantage for outside purposes. This fact is particularly emphasized if coke-oven gas can be sold for domestic heating and lighting at a price well above the actual cost of its manufacture.

In the following calculations use was made of the arguments discussed on the previous pages. The assumptions on which these calculations are based are stated elsewhere in the body of this paper. It should be explained that two alternatives were considered and investigated, namely, the installation of a gas-engine power plant using straight blast-furnace gas, and that of engines operating on a mixture of coke-oven gas and blast-furnace gas in the proportion 1 to 15. A further subdivision was thought necessary to account for a difference of opinion which still prevails among foundry-iron interests whether merchant furnaces of 350 tons or 450 tons capacity should be built. While the author does not feel competent to take sides in this controversy, he wishes to point out that, according to H. A. Brassert, many important considerations favor the installation of larger furnaces:

"Roughly, the cost of a plant of two 450-ton furnaces is \$2,000,000 complete with gas-blowing engines, modern ore-handling machinery, bins, etc. Two 350-ton furnaces will cost very nearly the same amount, as it would not be possible to save any appreciable amount of money on the larger items such as ore-handling machinery, gas-blowing engine equipment, etc.

"The operating cost of a 450-ton furnace is almost the same per day as that of a 350-ton furnace, with the exception of the materials charged, viz., ore, coke, and limestone, which are the same per ton but more per day. The cost above materials per ton, being the same per day in both cases, would be little more than seven-ninths of that of the smaller furnaces. For instance, if the cost above materials charged were \$1.50 per ton for the smaller furnaces, it would be about \$1.25 for the larger, thus saving 25 c. per ton of pig iron on 'cost above' alone. A saving should also be made on cost of coke per ton of iron, since a larger blast furnace can be operated more economically on fuel than a small furnace—at least such has been the experience at those plants where large furnaces of good design have been built with proper stock distribution. Large merchant furnaces making foundry iron have run on less than 2,300 lb. of coke per ton of iron, if coke of good quality is used. Smaller furnaces, such as foundry-iron interests are in the habit of building, cannot show anywhere near such practice over a period of years. Radiation losses are very much smaller on large furnaces and operation is less sensitive and more regular, old-fashioned beliefs to the contrary notwithstanding. The lowest fuel records on special grades of iron, including ferro-silicon and ferro-manganese, have been made on furnaces of the larger size."

Calculated Values

Item	Unit	2 B.F., 350 tons each	2 B.F., 450 tons each
<i>A. Blast-Furnace Gas Used for Power Purposes</i>			
1. Pig-iron production	24 hr.	700 tons	900 tons
2. Do.	Year	230,000 tons	300,000 tons
3. Coke consumption	Ton pig	2,400 lb.	2,400 lb.
4. Rate of B.F. gas production	Ton pig	170,000 cu. ft.	170,000 cu. ft.
5. Heating value of B.F. gas	Cu. ft.	101 B.t.u.	101 Btu.
6. Total quantity B.F. gas produced	24 hr.	120,000,000 cu. ft.	153,000,000 cu. ft.
7. Required for stoves, lost by leakage (40 per cent. total)	24 hr.	50,000,000 cu. ft.	63,000,000 cu. ft.
8. Remainder	24 hr.	70,000,000 cu. ft.	90,000,000 cu. ft.
9. Gas-blowing engine requirements. a. Normal blast pressure 15 lb. per sq. in.			
10. Gas : air ratio		1.39	1.39
11. Air required at tuyeres Item 4 × Item 1 1,440 × Item 10	Min.	60,000 cu. ft.	77,000 cu. ft.
12. Actual air required at Dyblie valves (5 per cent. added for blowing down stoves, leaky pipes, hot-blast valves, etc.)	Min.	63,000 cu. ft.	80,800 cu. ft.
13. Vol. eff. of blowing tube at 15 lb. blast pressure		90 per cent.	90 per cent.
14. Necessary displacement of tube for both furnaces	Min.	70,000 cu. ft.	90,000 cu. ft.
15. Work on adiabatic compression to 15 lb. (5 BHP per 100 cu. ft.; MEP = 11.5 lb.)	Hr.	3,500 BHP.	4,500 BHP.
16. IHP required in blowing cyla. (com- pression eff. 95 per cent.)	Hr.	3,680 HP.	4,740 HP.
17. BHP required at gas-engine shaft (mech. eff. of blowing tube 95 per cent.)	Hr.	3,900 BHP.	5,000 BHP.
18. IHP required in gas cylinders (mech. eff. of gas eng. 80 per cent.)	Hr.	4,900 IHP.	6,200 IHP.
19. Type of gas-blowing engines	Each	Single tandem 4 cycle double act- ing.	Single tandem 4 cycle double act- ing.
20. Principal dimensions	Each eng.	44 and 76 × 60 in.	44 and 76 × 60 in.
21. No. of gas-blow. eng. installed		5	5
22. No. of gas-blow. eng. operating		4	4
23. Net air piston area (15-in. rod)	Each tub	4,360 sq. in.	4,360 sq. in.
24. Net gas piston area (15-in. rod)	Each cyl.	1,344 sq. in.	1,344 sq. in.
25. Ratio of net areas : air : gas		3.25	3.25
26. Air-tub piston displacement per revolution	Each eng.	300 cu. ft.	300 cu. ft.
27. Speed required for full displacement	Each eng.	58 RPM.	75 RPM
28. IHP maximum continuous rating at 71 lb. MEP	Each eng.	1,650 IHP.	2,170 IHP.
29. BHP max. cont. rating at 71 lb. MEP (80 per cent. mech. eff.)	Each eng.	1,320 BHP.	1,740 BHP.
30. Gas-blowing engine requirements. b. Max. blast press. 25 lb. per sq. in.			
31. (MEP adiabatic compression = 17 lb. per sq. in.)			
32. BHP reqd. at gas eng. shaft	4 eng.	5,720 BHP	7,360 BHP
33. IHP reqd. in gas cylinders	4 eng.	7,120 IHP	9,200 IHP
34. MEP reqd. in gas cylinders	Each eng.	77 lb. per sq. in.	76 lb. per sq. in.
35. Gas consumption of gas-blow'g engines:			
36. Yearly average thermal eff. referred to BHP and 15 lb. aver. Blast pressure in- cluding (0.98) gas-cleaning efficiency		20 per cent.	20 per cent.
37. Heat consumption (15 lb. aver. blast pressure)	BHPH	12,700 B.t.u.	12,700 B.t.u.

38. Gas consumption (101 B.t.u. gas)	BHPH	125 cu. ft.	125 cu. ft.
39. Total gas consumption (yearly average)	Hr.	485,000 cu. ft.	625,000 cu. ft.
40. Do.....	24 hr.	11,700,000 cu. ft.	15,000,000 cu. ft.
41. Requirements of blast furnace auxiliaries (pumps, air compressors for mud guns, bells, etc., electric light and power for ore unload., scale and trans. cars, skip hoists, pig mach., etc., power produced in gas elect. engines).....	Hr.	60,000 cu. ft.	80,000 cu. ft.
42. Gas reqd. for auxiliaries.....	24 hr.	1,440,000 cu. ft.	1,920,000 cu. ft.
43. Surplus gas available for outside purposes (Item 8—Item 40—Item 42).....	24 hr	56,860,000 cu. ft.	73,080,000 cu. ft.
44. Do.....	Hr.	2,360,000 cu. ft.	3,060,000 cu. ft.
45. B.t.u. available (101 B.t.u. gas).....	Hr.	240,000,000 B.t.u.	308,000,000 B.t.u.
46. Theoretical max. surplus elec. power obtainable (full load: 23 per cent. therm. eff.; 15,000 B.t.u. per kw-hr.)	Hr.	16,000 kw.	20,500 kw.
47. Do.....	Ton pig	23 kw.	23 kw.
48. Unit size of gas engines installed.....	Each	TT 44 in. X 60 in. 83.3 RPM: Max. Cont. Rating 2,700 kw. (71 lb. MEP): overload capacity for 2 hr. 3,000 kw. (79 lb. MEP)	

NB. Gas-Engine Plant Operating Jointly with Existing Steam-Turbine Stations

49. "Factor of Safety" acct. shorter periods of gas deficiency occasioned by casting, checking, changing tuyères and smaller repairs on equipment.....		85 per cent.	80 per cent.
50. Practical max. surplus electric power obtainable.....	Hr.	13,500 kw.	16,500 kw.
51. Do (approx.)	Ton pig	19 kw.	18 kw.
52. No. of units in operation.....		5	6
53. No. of spare units (for internal service)		1	1
54. Total number of units installed.....		6	7
55. Max. cont. rating <i>all</i> units	Hr.	16,000 kw.	19,000 kw.
56. Max. cont. rating <i>operating</i> units.....	Hr.	13,500 kw.	16,000 kw.
57. Steam of 150 lb. gauge pressure recovered by exhaust-heat boilers at 70 per cent. to 80 per cent. average load 1.85 lb. per BHPH = 2.65 lb. per kw-hr.			
58. Do. from gas-blowing engines. Item 17 X 1.85 (approx.).....	Hr.	7,000 lb.	9,000 lb.
59. Do. from gas electric engines. 0.85 X Item 58 X 2.65 (approx.).....	Hr.	30,000 lb.	36,000 lb.
60. Total average steam available.....	Hr.	37,000 lb.	45,000 lb.
61. Average possible output turbo generators at 15.5 lb. per kw-hr.	Hr.	2,400 kw.	2,900 kw.
62. No. and rating (50° C. temperature rise) possible turbo generators of about 20 per cent. overload capacity.....		1-2,000 kw.	1-2,500 kw.
63. Per cent. steam capacity: gas capacity. Item 61 : Item 56.....		18 per cent.	18 per cent.
64. Possible max. cont. rating power plant (gas and steam) <i>all</i> units. Item 55 plus Item 62.....	Hr.	18,000 kw.	21,500 kw.
65. Do. (approximately).....	Ton pig.	25 kw.	24 kw.
66. Kw-hr. produced in gas elec. station. Item 56 X 8,760 X Item 67.	Year	100,000,000 kw-hr.	120,000,000 kw-hr.
67. Use factor of power plant. Item 66	Yearly	85 per cent	86 per cent.
Item 56 X 8,760			

68. Gas consumption of gas electric engines: Thermal eff. 21.5 per cent. 16,000 B.t.u. = 158 cu. ft. per kw-hr. 158 X Item 66.....	Year.	15,800 X 10 ⁶ cu. ft.	19,000 X 10 ⁶ cu. ft.
69. Aver. gas consumption gas electric engines (1 yr. = 365 days).....	24 hr.	43,000,000 cu. ft.	52,000,000 cu. ft.
70. Actual gas surplus available for power purposes. Item 43.....	24 hr.	56,860,000 cu. ft.	73,080,000 cu. ft.
71. Aver. utilisation factor of power gas. Item 69 : Item 70.....		76 per cent.	71 per cent.

B. Mixture of Blast-Furnace and Coke-Oven Gas Used for all Power Purposes

(Items 1 to 37 inclusive apply equally on this alternative)

1 cu. ft. of coke-oven gas of 500 B.t.u. per cu. ft. plus 15 cu. ft. of blast-furnace gas of 101 B.t.u. per cu. ft. = 16 cu. ft. of mixture of 125 B.t.u. per cu. ft.			
72. Gas consumption of gas-blowing engines. $\frac{12,700 \text{ B.t.u.}}{125 \text{ B.t.u./cu. ft.}} = \dots\dots\dots$	BHPH	102 cu. ft.	102 cu. ft.
73. Total gas consumed (yearly av.) by gas-blowing engines.....	Hr.	400,000 cu. ft.	510,000 cu. ft.
74. Do.....	24 hr.	9,600,000 cu. ft.	12,200,000 cu. ft.
75. Requirements of blast-furnace auxiliaries. (See Item 41.).....	Hr.	48,500 cu. ft.	65,000 cu. ft.
76. Gas mixture reqd. for blast-furnace auxiliaries.....	24 hr.	1,170,000 cu. ft.	1,560,000 cu. ft.
77. Blast-furnace gas remainder (Item 8)....	24 hr.	70,000,000 cu. ft.	90,000,000 cu. ft.
78. Coke-oven gas added for 1 : 15 mixture.	24 hr.	4,650,000 cu. ft.	6,000,000 cu. ft.
79. Total gas mixture supply.....	24 hr.	74,650,000 cu. ft.	96,000,000 cu. ft.
80. Surplus gas available for electric power. Items 79-74-76	24 hr.	63,880,000 cu. ft.	82,240,000 cu. ft.
81. Do. (yearly average).....	Hr.	2,650,000 cu. ft.	3,425,000 cu. ft.
82. B.t.u. available (125 B.t.u. gas mixture).	Hr.	330,000,000 B.t.u.	430,000,000 B.t.u.
83. Theoretical max. surplus electric power obtainable (full load; 23 per cent. thermal eff.; 15,000 B.t.u. per kw-hr.)	Hr.	22,000 kw.	28,600 kw.
84. Do. (approximately).....	Ton pig.	31 kw.	32 kw.
85. Unit size of gas engines installed. (See Item 48.).....	each	TT 44 in. X 60 in. 83.3 RPM.: Max. cont. rating 2,700 kw. (71 lb. MEP). Overload capacity for 2 hr. 3,000 kw. (79 lb. MEP).	

NB. Gas-Engine Plant Operating Jointly with Existing Steam-Turbine Stations

86. "Factor of Safety" (for definition see Item 49).....		86 per cent.	85 per cent.
87. Practical max. surplus electric power obtainable.....	Hr.	19,000 kw.	24,300 kw.
88. Pract. max. surplus elect. power obtainable (approx.).....	Ton pig	27 kw.	27 kw.
89. No. of units in operation.....		7	9
90. No. of spare units (for internal service).....		1	1
91. Total No. units installed.....		8	10
92. Max. cont. rating all units.....	Hr.	21,600 kw.	27,000 kw.
93. Do. operating units.....	Hr.	19,000 kw.	24,300 kw.
94. Steam of 150 lb. gauge pressure recovered by exhaust-heat boilers: at 70 per cent. to 80 per cent. average load 1.85 lb. per BHPH = 2.65 lb. per kw-hr.			
95. Do. from gas-blowing engines. Item 17 X 1.85 (approx.)	Hr.	7,000 lb.	9,000 lb.
96. Do. from gas electric engines. 0.85 X Item 93 X 2.65 (approx.).....	Hr.	43,000 lb.	55,000 lb.
97. Total aver. steam available.....	Hr.	50,000 lb.	64,000 lb.

98. Aver. possible output turbo generators at 15.5 lb. per kw-hr.....	Hr.	3,200 kw.	4,100 kw.
99. No. and rating (50° C. temperature rise) possible turbo generators of about 20 per cent. overload capacity.....		1-2,500 kw.	1-3,500 kw.
100. Per cent. steam capacity: gas capacity. Item 98: Item 93.....		17 per cent.	17 per cent.
101. Possible max. cont. rating power plant (gas and steam) all units, Item 92 plus Item 99 (approx.).....	Hr.	24,000 kw.	30,500 kw.
102. Do. (approximately).....	Ton pig	34 kw.	34 kw.
103. Kw.-hr. produced in gas electric station. Item 93×8,760×Item 104.....	Year	140,000,000 kw.	180,000,000 kw.
104. Use factor of power plant Item 103 Item 93×8,760.....	Yearly	85 per cent.	85 per cent.
105. Gas consumption of gas electric engines: Thermal eff. 21.5 per cent.; 16,000 B.t.u.=128 cu. ft. per kw.-hr. 128×Item 103.....	Year	18,000×10 ⁶ cu. ft.	23,000×10 ⁶ cu. ft.
106. Aver. gas consumption gas electric engines (1 yr.=365 days).....	24 hr.	49,500,000 cu. ft.	63,000,000 cu. ft.
107. Actual gas surplus available for power purposes. Item 80.....	24 hr.	63,880,000 cu. ft.	82,240,000 cu. ft.
108. Average utilisation factor of power gas. Item 106: item 107.....		77 per cent.	77 per cent.

Coke-Oven Plant

109. Coke required per day for blast furnaces. Item 1×Item 3.....	24 hr.	1,680,000 lb.	2,160,000 lb.
110. Do.	24 hr.	840 short T.	1,080 short T.
111. Coal required at 75 per cent. yield Item 110 0.75.....	24 hr.	1,120 short T.	1,440 short T.
112. Do. with allowance of 6 per cent. coal for coke breeze.....	24 hr.	1,230 short T.	1,570 short T.
113. Number of 13½ ton ovens 18 hr. coking time. Item 112×18 =.....		70	89
114. Total coke-oven gas produced @11,000 cu. ft. per short ton of coal.....	24 hr.	13,500,000 cu. ft.	17,250,000 cu. ft.
115. Coke-oven gas not required for power purposes (account utilisation factor, Item 108) and therefore available for sale: $\frac{1}{3}$ ×(Item 107—Item 106) yearly aver. approximately.....	24 hr.	900,000 cu. ft.	1,200,000 cu. ft.
116. Grand total coke-oven gas available for sale: Item 114—Item 78 plus Item aver. 115.....	24 hr.	9,750,000 cu. ft.	12,450,000 cu. ft.
117. Percentage of total coke-oven gas used for power purposes: Item 78—Item 115 ×100 approx.....		28 per cent.	28 per cent.
118. Percentage of total coke-oven gas used for sale for domestic heating and lighting. Item 116 Item 114×100.....		72 per cent.	72 per cent.

Cost of Producing Coke-Oven Gas

119. Total investment in coking plant.....		\$1,700,000	\$2,000,000
120. Fixed charges: 6 per cent. interest plus 5 per cent. amortisation plus 1 per cent. insurance and taxes = 12 per cent., Item 119×0.12.....	24 hr.	\$560.00	\$660.00
305.....			

121. Coking coal @ \$3.00 per long ton = \$2.67 per short ton. Item 112×2.67..	24 hr.	\$3,280.00	\$4,190.00
122. Conversion cost including all labor, material, repairs, acid, lime, bags for sulphate, etc.	Short T. coal	75 c.	72 c.
123. Do. Item 112×Item 122	24 hr.	\$920.00	\$1,130.00
124. Cost of by-product producer gas for heating coke ovens. (See p. 683) approximately	24 hr.	\$330.00	\$420.00
125. Cost of sulphur purification of coke-oven gas @ \$0.006 per M. cu. ft. Item 114×0.006	24 hr.	\$80.00	\$100.00
1,000			
126. Total charges	24 hr.	\$5,170.00	\$6,500.00
127. Credit for sulphate of ammonia @ 22 lb. per ton of coal @ \$60 per ton of sulphate. Item 112×22×60	24 hr.	\$810.00	\$1,040.00
2,000			
128. Credit for tar @ 6 gal. per ton @ 2½ c. per gal. Item 112×6×0.025.....	24 hr.	\$190.00	\$230.00
129. Value of coke as charged to blast furnaces @ \$4.25 per short ton. Item 110×4.25 =	24 hr.	\$3,570.00	\$5,490.00
130. Total credits	24 hr.	\$4,570.00	\$5,860.00
131. Net cost of total coke-oven gas. Item 130—Item 126	24 hr.	\$600.00	\$640.00
132. Net cost of total coke-oven gas delivered into holder. Item 131×100×1,000	M. cu. ft.	4.4 c.	3.7 c.
Item 114			
133. Selling price of coke-oven gas at gas holder (assumed)	M. cu. ft.	12.0 c.	12.0 c.
134. Net profit from sale of gas. Item 134—Item 133	M. cu. ft.	7.6 c.	8.3 c.
Item 116×Item 134			
135. Do. Item 116×Item 134 approx.....	24 hr.	\$680.00	\$1,000.00
1,000×100			
136. Do. Item 135×365 approx.....	Year	\$250,000.00	\$365,000.00

Cost of Blowing Blast Furnaces

137. Total quantity of air blown (displacement of blowing tube). Item 14×60×8760.....	Year	36,800×10 ⁶ cu. ft.	47,300×10 ⁶ cu. ft.
138. Cost of installation of gas-blowing engine equipment complete (including one steam turbo blower) approx		\$650,000.00 100 %	\$650,000.00
139. Subdivided into: Buildings.....		\$80,000.00 12 %	\$80,000.00
140. Engine equipment.....		\$530,000.00 82 %	\$530,000.00
141. Gas-clean. plant.....		\$40,000.00 6 %	\$40,000.00
142. Cost of Installation on displ. basis (operating engines only). Item 138 : Item 14.	Cu. ft. displ.	\$9.30	\$7.20
143. Do. on BHP Basis (all installed engines at maximum continuous rating). Item 138	BHP inst.	\$98.50	\$75.00
5×Item 29			
144. Fixed charges: 6 per cent. interest plus 7 per cent. amortisation plus 2 per cent. insurance and taxes = 15 per cent. Item 138×0.15.....	Year	\$97,500.00	\$97,500.00
Item 144×10 ⁶	Mill. cu. ft.	\$2.65	\$2.05
145. Do. on displacement basis. Item 137	displ.		

146. Operating expenses incl. gas purification, all labor, repairs and maintenance, lubricants, water and miscellaneous.....	Year	\$40,000.00	\$42,500.00	
147. Do. on displacement basis.				
Item 146×10^4	Mill. cu. ft.	\$1.09	\$0.90	
Item 137	displ.			
148. Value of blast-furnace gas @ 10 c. per mill. B.t.u. (seep. 682) $\frac{1,000 \times \text{Item 5}}{1,000,000} \times 10$	M. cu. ft.	1.01 c.	1.01 c.	
149. Cost of coke-oven gas (see Item 132)	M. cu. ft.	4.40 c.	3.70 c.	
150. Value of 1:15 mixture of coke-oven gas and blast-furnace gas.....	M. cu. ft.	1.22 c.	1.18 c.	
151. Cost of fuel (blast-furnace gas only used) $\frac{\text{Item } 40 \times 365}{1,000} \times \text{Item 148} \dots\dots$	Year	\$43,000.000	\$55,000.00	
152. Do. on displacement basis.				
Item 151×10^4	Mill. cu. ft.	\$1.16	\$1.16	
Item 137	displ.			
153. Cost of fuel (gas mixture used).				
Item 74×365 $\times$ Item 150.....	Year	\$42,800.00	\$52,000.00	
154. Do. on displacement basis.				
Item 153×10^4	Mill. cu. ft.	\$1.16	\$1.11	
Item 137	displ.			
155. Grand total cost of blowing blast furnaces (blast-furnace gas only used). Item 144 plus Item 146 plus Item 151..	Year	\$180,500.00	\$195,000.00	
156. Do. on displacement basis. Item 145 plus Item 147 plus Item 152.....	Mill. cu. ft.	\$4.90	\$4.11	
	displ.			
157. Grand total cost of blowing blast furnaces (gas mixture used). Item 144 plus Item 146 plus Item 153	Year	\$180,300.00	\$192,500.00	
158. Do. on displacement basis. Item 145 plus Item 147 plus Item 154.....	Mill. cu. ft.	\$4.90	\$4.06	
	displ.			
159. Recapitulation: Cost of Blowing Blast Furnaces.				
(A) Blast-furnace gas only used:	Yearly	Per Mill. cu. ft. displ.	Yearly	Per Mill. cu. ft. displ.
Fixed charges.....	\$97,500.00	\$2.65	\$97,500.00	\$2.05
Operating expenses.....	40,000.00	1.09	42,500.00	0.90
Cost of fuel.....	43,000.00	1.16	55,000.00	1.16
Total.....	\$180,500.00	\$4.90	\$195,000.00	\$4.11
(B) Gas mixture used:				
Fixed charges.....	\$97,500.00	\$2.65	\$97,500.00	\$2.05
Operating expenses.....	40,000.00	1.09	42,500.00	0.90
Cost of fuel.....	42,800.00	1.16	52,500.00	1.11
Total.....	\$180,300.00	\$4.90	\$192,500.00	\$4.06

Cost of Producing Electric Power

(Gas-Engine Plant Operating jointly with existing Steam-Turbine Stations)

A. Blast-Furnace Gas only used for Power Purposes.

160. Power plant capacity installed (see Item 55)	Hr.	16,000 kw.	19,000 kw.
161. Kw-hr. produced (see Item 66)	Yr.	100,000,000 kw-hr.	120,000,000 kw-hr.
162. Cost of installation of gas-engine power plant complete		\$1,450,000.00	100 % \$1,675,000.00
163. Subdivided into: Buildings		\$160,000.00	11 % \$185,000.00
164. Engine equip		1,180,000.00	82 % 1,370,000.00
165. Gas-clean. plant		110,000.00	7 % 120,000.00

166. Cost of installation on kw. basis: Item 162: Item 180.....	Kw.	\$90 00	\$88.00
167. Fixed charges: 6 per cent. interest plus 7 per cent. amortisation plus 2 per cent. insurance and taxes = 15 per cent. Item 162×0.15.....	Yr.	\$218,000.00	\$250,000.00
168. Do. on kw-hr. basis. $\frac{\text{Item 167} \times 100}{\text{Item 161}}$...	Kw-hr.	0.218 c.	0.208 c.
169. Operating expenses incl. gas purification, all labor, repairs and maintenance, lubricants, water, and miscellaneous. $\frac{\text{Item 169} \times 100}{\text{Item 161}}$...	Yr.	\$122,000.00	\$135,000.00
170. Do. on kw-hr. basis. $\frac{\text{Item 169} \times 100}{\text{Item 161}}$...	Kw-hr.	0.122 c.	0.112 c.
171. Cost of fuel. $\frac{\text{Item 68} \times \text{Item 148}}{1,000 \times 100}$	Yr.	\$160,000.00	\$192,000.00
172. Do. on kw-hr. basis.....	Kw-hr.	0.160 c.	0.160 c.
173. Grand total cost of electric power. Item 167 plus Item 169 plus Item 171.....	Yr.	\$500,000.00	\$577,000.00
174. Do. on kw-hr. basis. Item 168 plus Item 170 plus Item 172.....	Kw-hr.	0.500 c.	0.480 c.

B. 1:15 Gas Mixture of Coke-Oven and Blast-Furnace Gas used for Power Purposes

175. Power-plant capacity installed (see Item 92).....	Hr.	21,600 kw.	27,000 kw.
176. Kw-hr produced (see Item 103).....	Yr.	140,000,000 kw-hr.	180,000,000 kw-hr.
177. Cost of installation of gas-engine power plant complete.....		\$1,850,000.00	100 % \$2,200,000.00
178. Subdivided into: Buildings.....		\$200,000.00	11 % \$240,000.00
179. Engine equip.....		1,520,000.00	82 % 1,800,000.00
180. Gas-clean. plant.....		130,000.00	7 % 160,000.00
181. Cost of installation on kw. basis: Item 177: Item 175.....	Kw	\$86.00	\$81.50
182. Fixed charges: 6 per cent. interest plus 7 per cent. amortisation plus 2 per cent. insurance and taxes = 15 per cent. Item 177×0.15.....		\$278,000.00	\$330,000.00
183. Do. on kw-hr. basis. $\frac{\text{Item 182} \times 100}{\text{Item 176}}$...	Kw-hr.	0.200 c.	0.184 c.
184. Operating expenses incl. gas purification, all labor, repairs and maintenance, lubricants, water and miscellaneous....	Year	\$147,000.00	\$180,000.00
185. Do. on kw-hr. basis. $\frac{\text{Item 184} \times 100}{\text{Item 176}}$...	Kw-hr.	0.105 c.	0.100 c.
186. Cost of fuel. $\frac{\text{Item 105} \times \text{Item 150}}{1,000 \times 100}$	Yr.	\$220,000.00	\$272,000.00
187. Do. on kw-hr. basis. $\frac{\text{Item 186} \times 100}{\text{Item 176}}$...	Kw-hr.	0.157 c.	0.150 c.
188. Grand total cost of electric power. Item 182 plus Item 184 plus item 186...	Year	\$645,000.00	\$782,000.00
189. Do. on kw-hr. Basis. Item 183 plus Item 185 plus Item 187.....	Year	0.462 c.	0.434 c.
190. Recapitulation: Cost of Producing Electric Power.			
(A) Blast-furnace gas only used:			
Power-plant capacity.....		16,000 kw.	19,000 kw.
Kw-hr. produced per year.....		100,000,000 kw-hr.	120,000,000 kw-hr.
	Yearly	Per Kw-hr.	Yearly Per Kw-hr.
Fixed charges.....	\$218,000.00	0.218 c.	\$250,000.00 0.208 c.
Operating expenses.....	122,000.00	0.122 c.	135,000.00 0.112 c.
Cost of fuel.....	160,000.00	0.160 c.	192,000.00 0.160 c.
Total.....	\$500,000.00	0.500 c.	\$577,000.00 0.480 c.

(B) Gas mixture used:

Power-plant capacity.....	21,600 kw.	27,000 kw.
Kw-hr. produced per year.....	140,000,000 kw-hr.	180,000,000 kw-hr.

		Yearly	Per Kw-hr.	Yearly	Per Kw-hp
Fixed charges		\$278,000.00	0.200 c.	\$330,000.00	0.184 c.
Operating expenses		147,000.00	0.105 c.	180,000.00	0.100 c.
Cost of fuel		220,000.00	0.157 c.	272,000.00	0.150 c.
Total		\$645,000.00	0.462 c.	\$782,000.00	0.434 c.
191. Over-all cost of electric power adding to unit costs Items 174 and 189, respectively distribution cost of 0.4 c. per kw-hr. associated with transformation, transmission, sub-stations, etc. Alternative A (blast-fce. gas only)	Kw-hr.	0.900 c.		0.880 c.	
Alternative B (gas mixture)	Kw-hr.	0.862 c.		0.834 c.	
192. Profit derived from sale of electric power at selling price of 1.2 c. per kw-hr. Alternative A (blast-furnace gas only)	Kw-hr.	0.300 c.		0.320 c.	
Alternative B (gas mixture)	Kw-hr.	0.338 c.		0.366 c.	
193. Do. Alternative A (blast-furnace gas only). Item 66 X Item 192-A 100 approx.	Year	\$300,000.00		\$385,000.00	
Do. Alternative B (gas mixture) Item 103 X Item 192-B 100 approx.	Year	\$475,000.00		\$660,000.00	
194. Recapitulation: Profits derived from utilization of gases.					
(A) blast furnace gas only used for power purposes.					
Profit from sale of total coke-oven gas. Item 114 X Item 134 X 365 1,000	Year	\$375,000.00		\$525,000.00	
Profit from sale of electric power. [Item 193-A	Year	300,000.00		385,000.00	
Grand total profit		\$675,000.00		\$910,000.00	
(B) 1:15 coke-oven and blast-furnace gas mixture used for all power purposes.					
Profit from sale of coke-oven gas. Item 136	Year	\$250,000.00		\$365,000.00	
Profit from sale of electric power. Item 193-B	Year	475,000.00		660,000.00	
Grand total profit	Year	\$725,000.00		\$1,025,000.00	
Saving of Alternative B over Alternative A	Year	\$50,000.00		\$115,000.00	

CONCLUSIONS

The foregoing calculations show that the installation of 450-ton blast furnaces offers distinct advantages over that of furnaces of 350 tons capacity.

It is found that the cost of blowing the larger blast furnaces is less per blast unit and, therefore, less per ton of pig iron produced than that of smaller furnaces and, furthermore, that the unit cost of producing electric power from the available surplus gas is considerably lower.

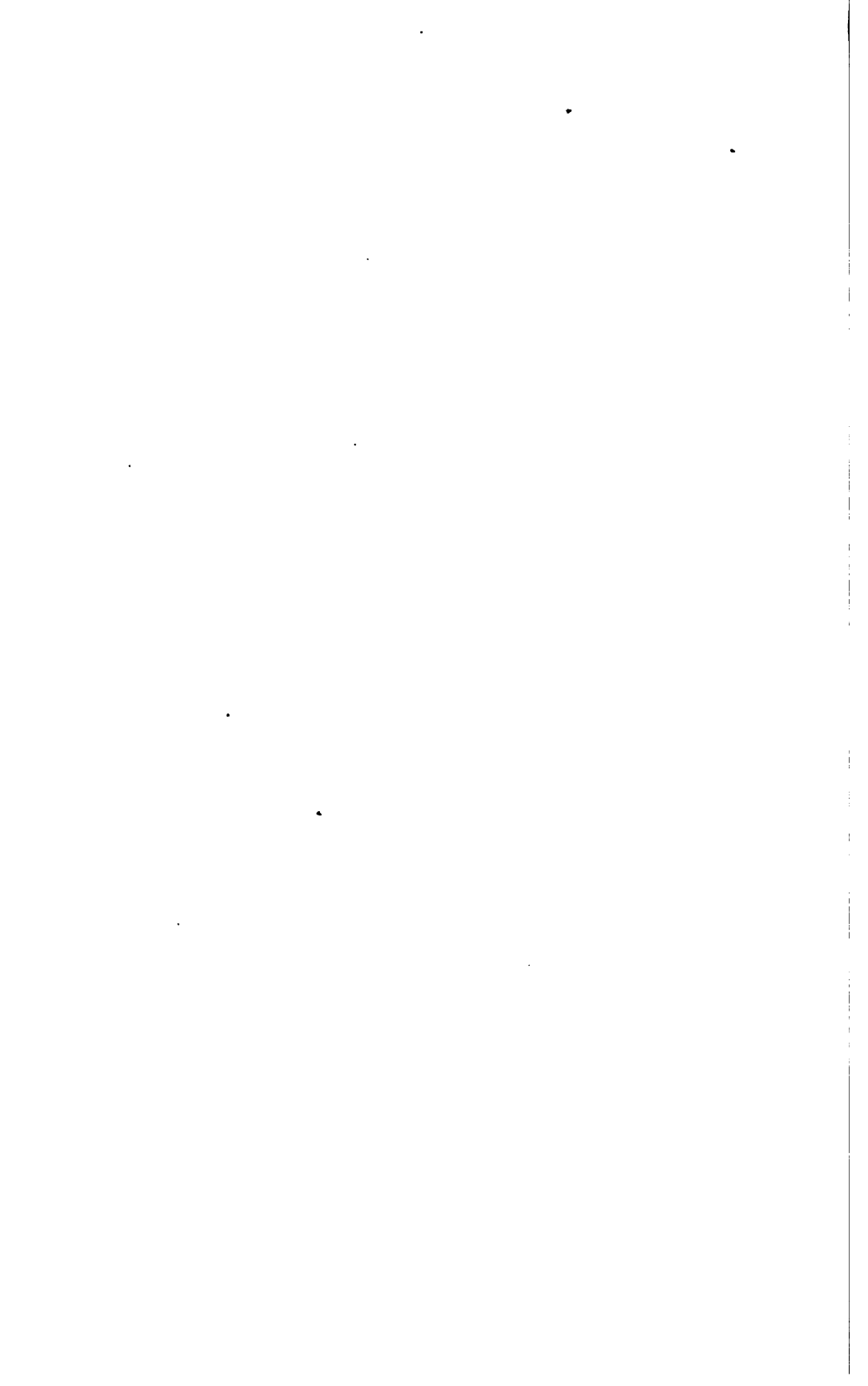
It is further shown that the unit cost of making coke-oven gas in a larger coking plant is a great deal less, and that the total revenues from

the utilization of blast-furnace and coke-oven gases are considerably greater with larger than with smaller blast furnaces.

The use of a mixture of blast-furnace and coke-oven gas for all power purposes is shown to yield substantial financial returns.

The cost of blowing the blast furnaces using a gas mixture for operating gas blowing engines is exactly the same in the case of smaller blast furnaces, and, with larger furnaces, it is somewhat lower than when using straight blast-furnace gas for this purpose.

According to these calculations, the general use of such a gas mixture for power purposes results in a very handsome annual saving, especially when larger blast furnaces and a correspondingly larger coking plant are installed.



DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at a meeting of the Institute. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y.

The Safety of Underground Electrical Installations

BY C. M. MEANS, PITTSBURG, PA.

(New York Meeting, February, 1914)

CONSIDERING the hazard involved in mining operations, statistics show that a very small percentage of accidents is chargeable to electricity. These accidents do represent quite a large percentage of those that are preventable and they are the direct result of the introduction, for purely economical reasons, of a dangerous element. The introduction of electricity in mines should decrease the hazard, and in no case should electricity be applied to the mechanical operation of equipment if by so doing the dangers incidental to mining are increased.

The greater number of accidents are the result of persons coming in contact with exposed conductors at potentials varying from 250 to 500 volts direct current. The use of alternating current at higher potentials than these is quite common in large mines, but it is very rare that an accident happens from this source. This is explained by the fact that where these high voltages are warranted, proper precautions are taken, and the installations are directed by those who fully appreciate the dangers incidental to the work. Direct current is in much more general use than alternating current because of its adaptability to haulage locomotives and the low cost of installation in small operations. We are, however, coming to a more extended application of alternating current for the operation of mechanical devices used in connection with mining.

Our underground direct-current wiring system is an evolution from the surface trolley and feeder systems. This is probably due to the fact that our earlier successful applications were electric locomotives, which required the use of a trolley wire. The trolley current has been almost banished from industrial establishments on the surface because of the hazard involved, yet we use it indiscriminately underground, where the dangers from accidental contact or fire are infinitely greater. This does not mean that the underground trolley systems should be eliminated, but it does imply the proper safeguarding of such equipment as is necessarily a part of the trolley systems.

It is a fact that the men now employed in the installation and maintenance of mining equipment may be in many cases incompetent or not thoroughly familiar with the work, but they are the men who must do the work and, in order to do it properly, it is necessary that they be educated

and guided in their task. Men who have been trained in industrial plants on the surface do not care to take up mining work, and the men to do underground electrical work must be recruited from men actually working in the mines. These men have no training except that gained from association with men engaged in the work. The result is, they do their work in such a manner as seems to them the most expedient with the results to be attained, and not in keeping with any clearly defined method or studied system.

For all electrical work on the surface we have the rules of the Underwriters' Association. Electricians and wiremen familiarize themselves with all requirements of the Underwriters, and the result is that their work is done in a thorough and safe manner. A complete set of electrical rules similar to those of the Underwriters' Association, but made applicable to underground work, would go a long way toward solving the problem, if they were made suitable for, and received, general application.

These rules would naturally be evolved from all data available and an investigation of all electrical accidents over a period of time; and a complete analysis should be made of causes, as well as methods to prevent a recurrence in the future. We have available the rules contained in the bituminous mine law of Pennsylvania and other States, rules of the Underwriters' Association, and rules of certain mining corporations and municipalities, that could be used for a basis. Any set of rules, no matter how carefully compiled, will naturally meet with a considerable amount of opposition and criticism, and a large part of the criticism will be warranted. This very feature will result in devising a set of rules that will meet the situation in its entirety, and make it possible to almost eliminate this class of accidents.

The problem of working out such a set of rules is a very formidable one, but no more difficult of solution than that which the Underwriters' Association has already solved or is successfully solving. It is fully apparent that additions or changes must be made from time to time to keep pace with an industry that is continually being developed and expanded.

The electrical rules contained in the bituminous mine law of Pennsylvania have been in effect something over two years, but last year represented the first opportunity we have had to judge the operation and effect on fatalities resulting from the use of electricity. While the exact records are not available, it is safe to say there will be a material decrease in the number of fatalities from the use of electricity in this district, and this in face of the fact of a very material increase in the use of electrically driven devices used in the production and transportation of coal.

These rules represent a first step in the standardization of electrical equipment and wiring as applied to underground workings, and the results stated are conclusive proof of what can be done along this line. These rules have resulted in the education of the men who do the work, and

they now know, in a general way, what they are required to do. Prior to the enactment of this law, the use of electricity in mines was tolerated but not authorized, and not subjected to any rules or regulations. It is only natural to suppose that this resulted in installations of all kinds. Some installations represented an unnecessary expense in doing everything possible to meet every restriction that might later be placed on the work, but a large number of the plants were put in simply to do the work, with very little regard to the safety of the employees. This is all changed now, and each operator knows what is required, and, wherever possible, meets all of the provisions contained in these rules.

These rules met with more or less opposition when first incorporated in the mining law, but they now meet with the favor of all progressive mining companies and have been of material value to all concerned.

Instead of restricting the use of electricity, these rules have caused a very material increase in this method of transmitting power to operate the different mechanical devices used in the production of coal, and are of material value to the coal industry in this region, as well as to electrical and kindred industries.

When the Underwriters' Association introduced rules governing electrical work, inspectors were employed to see that the work was done in keeping with the standard suggested by their code. Formerly these inspections covered all work done where insurance was carried, but as the workmen became more skilled the inspections were less comprehensive, and under certain conditions were omitted entirely.

For a period of time it will be necessary to employ a certain number of electrical inspectors for underground work to see that the rules are complied with. An inspector would be of little value unless he had a definite set of rules on which to base his recommendations. His duty will be to act largely in an advisory capacity and to interpret the rules laid down. The mining departments of the different States employ a certain number of mine inspectors, who can take care of the electrical work after they get entirely familiar with the rules and application, except where new schemes or unusual installations are involved. It may require some little time for these inspectors to become sufficiently familiar with electrical equipment and its operation, but a knowledge of this phase of the situation will be just as essential and as readily acquired as that of ventilation.

In the bituminous fields of Pennsylvania the mine inspectors paid very little attention to the electrical equipment so long as the use of electricity was simply tolerated, but just as soon as its use was authorized, and rules formulated covering the work, they familiarized themselves with the rules and their application, and in the average installation they are able to judge intelligently as to the safety of the equipment.

It is not within the province of this paper to suggest who should work out a proper set of rules or how they should be applied. The increased

safety that would be secured would fully warrant the co-operation of our government, both National and State. Electrical manufacturing companies should be very much interested because of the commercial advantages gained by reducing the hazard, thereby popularizing the use of electrically operated devices. The mining companies should also be interested because of the reduced hazard to employees and property that would naturally follow. A more extended application of electricity would be warranted with reduction in costs of operation. All safety organizations, as well as engineering societies, would be interested.

Taken in its entirety, considering the increased safety that would naturally follow, the commercial advantages to be gained, and the large number of interests involved, the expenditure of the necessary time, labor and money is fully warranted in the formation of a proper set of rules covering this work.

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The Segregation and Classification of the Natural Resources of the Public Domain

BY FREDERICK F. SHARPLESS, WESTBURY, L. I., N. Y.

(New York Meeting, February, 1914)

THE term "segregation," as here used, means the separation of certain natural resources into groups, consisting of one or more members, with the idea that when thus segregated, each group may be more easily and effectively administrated. We may, for example, consider surface rights as distinct from underground rights, and stop there; or we may go further, and deal separately with timber, water, and agricultural rights, or, going underground, we might deal separately with such groups as precious and base metals, clay, oil, gas, etc. The present paper contemplates only the separation so far as practicable, for administrative purposes, of surface from mineral rights.

"Classification," in this paper, has reference to the groups into which the government has divided, is dividing, or will hereafter divide its natural resources; first, into the broad classes of mineral and agricultural lands; and, second, into coal, oil, phosphate, brine lands, etc., the central idea being the separation into natural groups for the purpose of simplifying administration and for the purpose of encouraging maximum development and minimum waste.

The two subjects are in some respects quite distinct, but as my argument develops, I think it will be obvious why they are discussed in the same paper.

In the pursuit of our professions as mining engineers, geologists, or operators, we are continually confronted by conditions with which our present mining laws or regulations are incompatible. It may be a conflict, hardship or injustice, a piece of favoritism, or of unnecessary red tape; or we may see lack of development in a promising locality, and wonder what is the reason. Often we can see where a modification, slight or radical, in the laws would have obviated the difficulty without doing harm to any of those immediately concerned. Such alterations as individuals could intelligently suggest would be based on a relatively small number of situations occurring in their experiences. The published replies to the queries formulated by the various committees on mining law appear generally to reflect personal experience. Concerning a few points, there is a marked uniformity of opinion, while on other points opinions

appear to be almost irreconcilable—simply due to the fact that individual experiences and observation must be rather limited and not because of irreconcilable differences.

The object of altering our present laws is not to compound a panacea for all the ills to which mining is susceptible. There are certain changes which, because of their obvious advantages, we may be able to procure; the necessity of other changes is less obvious, and respecting these there is little probability of securing new enactments. Nevertheless, those of us who believe that the latter are right and proper, should give our testimony in their favor, and show all of the weakness that we believe exists, even though we know that our suggestions will, for the present, receive little consideration. The greatest good for the greatest number is the end for which we must all strive; and in giving our approval to one recommendation and withholding it from another, we should try to view the question as broadly as possible, and not be influenced to too great an extent by our own personal experience and desires.

It is of prime importance in connection with the subject of mining law to arrive at the fundamental conception of proprietorship of the natural resources of the public domain.

In the early days of mining, all mineral rights were held by the Crown, not only for the purpose of securing the precious metals for coinage, and for the "dignity of the Crown," but also that others than owners of surface rights might be encouraged to work underground, that underground resources might not lie idle because of surface occupation. Later, and up to the present time, various enlightened peoples have held that, for one reason or another, the fee of mineral land should remain in the State or central government.

Our Federal government has, from time to time, taken title to the major portion of the lands, outside of the thirteen original States, as trustee for all citizens of the United States, with the object of administering the trust to their best advantage. There is nothing in the original grants or in subsequent enactments to indicate that there was or ever had been any intention of retaining the fee of mineral lands, timber rights, water rights or other resources in the government or in the people. There was nothing in the trust requiring or preventing alienation. The prime object was that the natural resources of this immense area be used to the best advantage of all of its citizens. Generous grants were made to various States for various purposes, and the lands so granted passed entirely from Federal control and became subject to State legislation. Some States, in recent years, have forgotten whence they had their origin, and have expressed resentment at the Federal control of lands within their boundaries, not remembering that the government lands are lands belonging to the citizens of the United States and not to the citizens of any particular State.

I think it will be generally admitted that the owners of public lands and rights are the citizens of the country, and it is the business of the government to segregate, classify, sell or lease these lands as, in its wisdom, may seem most advantageous for all citizens.

In the administration of natural resources, we must bear in mind some important differences. Mineral rights and surface rights bear quite different relations to society. Surface rights have a permanent, underground rights but a transient value. The more intensely a farmer cultivates his land, the more valuable does it become to him and to the community. If development takes the shape of permanent and useful structures on the land, the increase in value to the individual and to the State may reach vast proportions. Indeed, it is not possible to anticipate the maximum usefulness which surface rights may acquire; but we know that when these rights are being used to the best advantage the country is also reaping the greatest benefit, and it is then that the life of the right appears longest and most useful.

A mineral right is of a different nature. The more it is worked, the smaller becomes its intrinsic value. It is of value to the community only at the time, and in proportion to the extent of its productiveness; but the greater this temporary usefulness, the shorter its duration.

The agricultural claimant locates a "homestead," while the prospector locates a "claim." The former indicates permanency of tenure, while the latter suggests a temporary possession.

A difference in the nature of agricultural and mineral land was recognized by Congress, when it passed an Act in 1879 calling for the classification of the public lands by the U. S. Geological Survey.

The output from a mineral right is, in many cases, a public necessity. The output from surface rights is much less liable to be so. The output of a mineral property being transient, the public has but a temporary interest in its development. The resources of the surface being permanent, the public will always have an interest in them.

The owner of a mineral right should receive every encouragement to develop his resource, to use it, and get out of the way, while the owner of the surface should be given every encouragement to make his improvements permanent and of ever-increasing value.

We do not all see the distinction between the ownership of the surface and of that which lies below the surface; but the arguments of those who do not see the difference dwell more upon the feasibility of regarding them as identical than they do upon proof that they are identical. We have, in this country, been regarding them as identical for so long that many of us believe that they are inseparable, and it is this belief, rather than any real difficulty, that stands in the way of segregating surface from underground rights.

If it is true that there is a marked difference in the nature of the rights

referred to, then the government, in assigning those rights, should not confound them. It should treat them separately, safeguarding fully the interest of the new and the old owner. It has been found in other countries, and will be found in this, that with surface rights segregated from mineral rights, regulations may be enforced with greater ease, with less inconvenience to the interested parties and with increased usefulness of the rights to the community at large, than when grantees hold all rights within the boundaries of their concessions.

In the early days of our history, we were rich in undeveloped resources, lands, minerals, water, and timber, beyond any possible requirement then apparent. We were rich in everything except population; and we gave liberally of all rights, without conditions, in order to secure this population. There appeared to be no reason for withholding, even temporarily, any of our resources. It was a natural policy to adopt, and one that has resulted in a marvelous development within an incredibly short time. Whether it has produced the greatest good for the greatest number, over the greatest time, is questionable; but that it fulfilled the requirements of the period is beyond doubt.

Suggestions have been made, to the effect that laws under which this marvelous development has taken place should not be modified, lest we hinder the rapid march of progress. Surely we do not want to curb progress, that must be farthest from our thoughts; but progress at the price of prodigality cannot go on forever.

Conditions have changed and are changing rapidly; some policies that were in force 20 to 50 years ago are not applicable to present conditions. Fundamental alterations are forcing us to change our views as to what policies are best. The signs of the times are pointing in new directions.

In order that progress may not be halted, we must change our laws and keep open a field for the uninterrupted exercise of the energies of the coming generation, giving it, so far as we are able, opportunities equal to those that have been given in the past.

One of the changed conditions to which I refer is, that a very large proportion of the public domain has already passed from the control of the Federal government, and the area over which the prospector may roam is becoming more and more confined. Both prospector and agricultural claimant must now do considerable searching to find a desirable locality. We are approaching the conditions of some of the older countries, where the governments no longer hold title to any considerable area of surface rights, but where, owing to the existence of that antiquated policy of segregation, the Crown or the government still holds some mineral rights of importance.

The first paragraph of the Prospectus, so familiar to all of us:

"The surface of this district has barely been scratched."

is growing further from the truth every year. The "unscratched" districts are very scarce, and if the policies of the past are to be continued, it will not be many years before we have given title to all of the good "scratching" ground, and the day of the prospector will have passed.

For several years, we have been discussing the cause of the decline and fall of the prospector; and the most potent reason for this decline appears to be the lack of a good country in which to prospect. We have deeded immense tracts to railroads, upon which the prospector has no right to go; we have deeded wide areas to agricultural claimants and we have deeded mining lands with prodigality, until we have left only those lands classed as mineral-bearing, yet devoid of such outcrops as once made the life of the prospector an interesting and exciting existence, if not always a profitable one. Generally, there has been no provision in the railway land grants whereby the Federal government would have any further interest in the grants, if in the course of time they proved to be more valuable for mineral than agricultural purposes; and it has been the same with the lands granted to individuals under agricultural patents.

Not only has there been an actual change in conditions, but the public mind is changing; we are looking at things from a different point of view than that of 50 years ago. What seemed to us right and proper then, may seem questionable to-day. The signs of the times point toward Federal restriction, if not toward Federal control.

For a long time, personal ambition, initiative, and accomplishment have gone unbridled until excesses have been committed that trespass on the rights of society. It is to curb these excesses that it has been proposed to place one industry after another under government control, with a tendency toward socialism. The pendulum swinging from extreme freedom of the individual or corporation on one side to socialism on the other, will probably come to rest at a point where business is conducted under certain governmental restrictions. However much some of us may regret to see "interference or competition" by the government, as Dr. Raymond puts it, it is probably here to stay; and the sooner we adapt ourselves and our laws to the changed views, the better off will we be.

Was the policy of those who have gone before us so bad? And have we done properly in alienating ourselves so completely from our patrimony both surface and underground? I believe that, under the circumstances, the policies adopted and followed for so many years were good. A mistake was corrected when the Homestead Act of 1862 was passed. After that date, the policy of providing public revenue from the disposal of the public domain was abandoned. That many other mistakes were made is absolutely certain; particularly is this true in regard to the development of our mineral resources. In those days, there were few people and fewer railways; both were needed; there was neither time nor money for careful investigation.

It was not intended, when deeding lands to the railways as a bonus for construction, that the mineral resources of the country should be tied up; indeed, it was not intended that any title should be given to mineral lands. That was an accident, a mistake. The same may be said of all agricultural patents that have been given to corporations or to individuals. The development of the mineral resources of those lands was simply overlooked in the broader necessity of getting a population upon arable lands and means of transportation to enable that population to become self-supporting and add to the prosperity of the country.

Going back still further, to the lands of the Mississippi valley; the grantors of the fees to the timber areas of Minnesota, or the agricultural lands of Wisconsin, Missouri, and Oklahoma, while they might have fully realized that they were deeding mineral rights, certainly could not have thought of this feature seriously, or more consideration would have been given to those rights, in which the whole of the American people were interested.

I think it may be regarded as a very serious mistake to have deeded, for a few dollars, lands that are to-day worth hundreds or thousands of dollars per acre.

Those lands were deeded for the use that could be made of their surface rights; and any enhancement due to efforts of an owner was a legitimate gain to him and to his heirs, but when through an accident, pure and simple, that owner found himself rich, with something that he did not buy or create by his own efforts, when he found himself possessed of something of value that did not belong to him, but did belong to the people and which the people did not intend to give him, then most certainly a mistake was made.

The mistake was not that of failing to classify lands properly, and deed only agricultural, mineral, or timber rights. Such a classification would have been impossible at that time; for even with the strides that have been made in geology during the last 50 to 75 years, it is still impossible to classify accurately. Even to-day, in those very districts cited, with a tremendous amount of underground knowledge available, no geologist can say, pending actual development, exactly what areas will be more valuable for mineral than for agricultural products.

The big mistake was in not inserting in deeds to surface rights a clause to the effect that if and when mineral discoveries should be made, the public interest in those minerals should be preserved. No provision was made for utilizing underground rights to the best advantage for the common good; they must lie idle until, in the wisdom of those who never bought them, they might be developed to their owner's personal advantage.

There were other mistakes made, some of them perhaps more serious than the one mentioned, but they have not to do with the subject of this

paper and will not be considered here. The mistakes of the past cannot be rectified, and if we go on alienating surface and mineral rights in the same manner, many of them will be repeated in the future. From time to time, enactments and regulations have been adopted to remedy previous defects; but they have not been as radical as conditions warranted. In order that we may not continue to repeat the mistake referred to, the logical thing to do would be to segregate the surface from underground rights and treat them as the two distinct resources that they are, alienating the one or the other as it may be sought for commercial development.

If this is not done, then more than ever do we need a careful classification of our lands not only into timber, agricultural, and mineral lands, but a further refinement into the kind of mineral, as coal, oil, phosphate, iron, precious metals, etc., and however far such classification is carried, we can see that, in all probability, a case will soon arise in which it has not been carried far enough.

We know to-day that it would be advantageous to have all of our coal, oil, gas, and brine lands classed separately, that we might apply different regulations to them; but in spite of our advanced geological knowledge, we cannot tell beyond question what areas are going to produce any one of these substances and what may produce two or more of them. We cannot even tell with any degree of accuracy what areas may or may not come under the broad class of mineral-bearing, let alone a subdivision of the minerals. Where then will a further attempt at classification lead us?

The classification that has been done by agents of the government has been well done. With a vast unknown area to map and classify, and limited means with which to accomplish it, the amount of work done has been remarkable; and we wonder, not at the mistakes, but at the remarkable accuracy that has been shown.

It would seem that in advance of actual discovery our geologists and the government would be attempting the impossible in striving to classify further than has already been done on the unoccupied areas of the public domain, and yet the necessity of varying regulations to suit the varying mineral conditions is obvious.

Can any better work be done in the future than has been done in the past? Yes, undoubtedly; but in many cases it will still be unsatisfactory. The doubtful areas will remain subject to doubt until actual discovery is made, and there will be many cases where absolutely unthought-of minerals will be found in unsuspected places.

If I am correct in the assertion that it was the intention of the Federal government to hold the public domain as a trust for the benefit of all of our people; if our forefathers were correct in separating mineral from non-mineral bearing lands; and if I am correct in stating that an exact

classification is impracticable, if not impossible, what may be done to harmonize these three propositions? It must be something to protect the public interest in lands; it must protect the holder of mineral rights and surface rights; and it must permit us to adapt different regulations to different natural products. That something has as its foundation the segregation of mineral rights from surface rights. Whether we do that or not, we must certainly classify various mineral rights for administrative purposes. The necessity of classification is so obvious as scarcely to require argument or proof; our present laws require it and conditions demand it. What is being done and what has been done in the way of classification is admirably set forth in *Bulletin* No. 537 of the U. S. Geological Survey, issued in 1913, which shows also the aims and objects of classification and the necessity of carrying this procedure to far greater lengths than have yet been attempted.

In March, 1879, Congress passed a law doing away with the Territorial surveys and establishing the U. S. Geological Survey. This enactment provided for the classification of the public lands and for geological examination of the public mineral resources. Classification, under this law, into mineral, agricultural, and timber lands began as soon as appropriations were available for the purpose, and continued on the same lines up to 1906, when, through instructions issued from the Department of the Interior, a broader interpretation was given to the original enactment, and classification was begun with the object of facilitating the administration of public lands.

Quoting from *Bulletin* No. 537, previously referred to:

"It is apparent, although it has nowhere been expressly stated by Congress, that the fundamental principle guiding that body has been to dispose of each tract of the public domain for the use to which it is best adapted. Thus the laws have provided that agricultural entry should not be made upon valuable mineral lands, that lands containing deposits of coal should be sold only as coal lands, and so on for all other classes of land."

In pursuance of this idea, withdrawals from the public domain have been made from time to time, to be again restored to entry when the lands have been properly classified, or regulations have been adopted under which the mineral rights may be developed. In most of these classifications, the land has been denominated coal, oil, phosphate, agricultural, or forest land, each parcel being placed under that class for which it seemed best adapted.

It was not until a comparatively recent time that any segregation of surface from mineral rights was made; but this has now been done with both coal and phosphate lands. Agricultural claimants may take up the surface rights in certain districts without acquiring rights to any of the coal or phosphate lying under them.

The complete classification of the public lands is a stupendous under-

taking. Up to the present time, only the most urgent cases have received the attention that they require. If the classification is to be followed to its logical conclusion, there will be work for the Geological Survey for many years to come, so long as there are any natural resources that have not been alienated by the government. The ideal plan would be to have every district properly and minutely classified before any of the resources were disposed of, and preferably before they were applied for. This, of course, is a practical impossibility. Indeed some one of the resources of a tract may not be known until after another is exhausted, and it is utterly impossible for any geologist, chemist, or engineer to look into the future far enough to provide for what may ultimately be found. The government has never made any provision for a complete classification of the public domain. It would be a very heavy expense and one of questionable propriety for several reasons; but if we could have such a classification with a flexible arrangement permitting of alterations as knowledge increased, it would be of immense value in the administration of the public domain.

At the time any piece of land is applied for, one of its resources will no doubt have been recognized; but that all of its possibilities have been foreseen is improbable. When one useful resource is recognized, and applied for, it is neither fair nor right that the applicant be given that for which he has no use and for which he does not care; it is not fair that the granting of rights be held up pending an indefinite period of investigation of those resources for which the applicant has neither desire nor need; nor is it right that the government be put to the expense of investigating resources that are not asked for.

To give the applicant that which he wants as early as he wants it, to avoid classification expense by the government at a time when it is not absolutely needed, and to conserve the rights of the people—all this may be accomplished simply by segregating the rights into certain groups and disposing immediately, under appropriate laws, of the right asked for.

An objection that is offered to classification is that it is regarded as impracticable, and instances are referred to where, in the past, certain lands were classed as agricultural that are now known to be mineral, and are not open to prospecting. Rather than an argument against classification, I take it that this really is a strong argument for more careful classification in the future. Those using the above argument are opposing segregation also; and yet had segregation been in vogue at the time these lands were patented, the complaint now made would have no existence.

Segregation of mineral rights would injure the farmer, the timber owner, and perhaps the town-lot owner, in that it might take away from him his rights in something that he had not paid for, was not expecting, or

was procuring by fraud. But so long as he is entirely protected in what he did buy, his rights are not comparable with those that should be reserved for the miner or one who is willing to risk a stake to see what is under the surface. It is useless to classify now, and expect such classification to hold; we must have something flexible through which we can make adjustments as occasions arise.

It is noted that many of those who argue against leasing, classification, or segregation, and in favor of alienation of everything, say: "Let there be a proper classification and then stick by that classification." But, they do not say how we are to make a proper classification to-day, and to-day is when it is needed. To-day we cannot tell with positiveness what minerals will some day be found. If we could, I think that the most of us would join in saying "classify properly and then stick by that classification, selling or leasing," but as we cannot classify for all time to come, let us segregate the surface rights from the mineral rights, and when one after another valuable mineral is found, we can apply appropriate legislation.

The present agitation with regard to radium is much to the point. It is proposed to withdraw all public lands from locations that are supposed to contain radio-active elements. In view of our present very limited knowledge of this element and its associates, I think such withdrawals are going rather far. This will certainly not encourage prospecting in the public domain; and if radio-active elements are as valuable as we hope they are, the one thing that we want to encourage is the prospecting for them. It is suggested that the government will do the prospecting. With all faith in the U. S. Geological Survey, and with all due respect to it, I do not think we should call on the Survey to do our prospecting. Let the regulation come in the production, or sale, or exportation of the product, but do not tell the prospector that he must not hunt for the element. Here again the remedy is the segregation of surface from mineral rights. Let the surface go for agricultural or other purposes; if gold is found let that go too; or if iron or coal, let them be operated under regulations applying to those substances; and if radium is found let regulations be applied to suit the emergency; but do not withdraw the land from entry for those purposes for which we know that it is useful. Just how far it may be advisable to go with segregation at the present time, is a question; but the work that has been done by the government in this direction has been so satisfactory that it certainly is practicable to go much further.

Owing to the fact that agricultural rights have been interfered with by the withdrawal policy of the government, and because it is extremely unfortunate to interfere with agricultural settlement when there is any demand for the land, certain segregation or separation acts have been passed, covering, however, certain lands only. The first Act, March, 1909, provides for the case of a settler who has selected for agri-

cultural purposes non-mineral land which is reported later to be coal land. The settler may acquire title to the surface only, and be entitled to recover damages if the surface is damaged or the farm interfered with by subsequent mining operations—the title to the coal, of course, remaining in the government.

The second Act, that of June 22, 1910, permits agricultural entries on land already classed as coal land. The agricultural entry is, of course, for surface rights only. A third Act, of Aug. 24, 1912, permits the filing of agricultural claims over certain areas in Utah already classified by the government as oil or gas land.

Bills have been introduced extending this principle to lands in other States than Utah and to phosphate lands in Idaho.

Thus, in a very few cases, the government is segregating surface from underground rights with the object of permitting the surface to be used just as soon as any one wants it, and permitting this without alienating its rights to the unknown mineral resources below the surface.

Quoting from Secretary Fisher:

"The law at present does not provide for the creation of any rights in supposedly mineral land, except by the issuance of patents, and in that regard Congress has provided that a patent can follow only on a legal location and has said, 'but no location of a mining claim shall be made until the discovery of the vein or lode within the limits of the claim located.'"

Because of this difficulty of securing title to deep-seated deposits, a certain area in Arizona was withdrawn in September, 1912, from any but mineral entry. This tract is one on which no mineral out-crops, but which members of the Geological Survey regard as favorable for the existence of deep-seated copper deposits. This land will be held by the government pending such discovery. In the meantime, the surface can be used for no other purpose. By segregating, the surface could be used for any purpose whatever and the mineral title held back until there was sufficient reason for doing the deep work.

Under the existing laws, the locator of a placer claim secures his rights under conditions far from satisfactory. He must make affidavit that there is no vein or lode within the claim, also that it is not taken up for the purpose of controlling water or for the use of timber. And when he has sworn to these exceptions and secures his patent, he is liable to lose his title at any time because some one else believes that fraud has been committed.

A valuable vein may be discovered; a contest is almost sure to be filed; and the innocent party is put to heavy expense, if he does not lose his property. Again a low-grade vein may be opened which because of local conditions is of no commercial importance. In the course of time, with improved transportation and better methods, this vein becomes a "commercial proposition"; but the vein is not locatable because of previous

alienation of the surface and everything within the surface. It is a resource that has been lost to the prospector and to the public, and thus an injustice has been done in granting what was not asked for or paid for. Had the surface or placer rights been segregated from the vein rights, the original locator would have been free from litigation, and the public's interest in the resources not asked for would have been conserved.

If segregation were in force at the present time, early classification would not be so essential as we now consider it to be. We would not have to class large areas as coal, oil, phosphate, or salt lands, probably including in such classification many acres of no value for mining purposes, and omitting many acres valuable for the underground rights. We would simply give title to the surface; or, if it was the mineral constituent that was the main feature of value, the government could permit its exploitation under appropriate regulations for that particular substance. No agricultural or other lands would be held up for lack of classification; and the expense of an unnecessary or useless classification would be avoided.

With segregation in force, lands would classify themselves when minerals were discovered and would automatically subject themselves to the regulations belonging to their proper class. If new minerals are discovered, the value of which is at present unknown or uncertain, the government, not having disposed of its rights, will be in a position to formulate regulations that will encourage development and exploration. If our laws are based entirely on facts, eliminating all theories and opinions, we can certainly expect better results. Basing law on facts will prevent the issuance of titles where undeserved, and where fraud may be intended.

Alienation may or may not follow segregation. If surface rights are to be alienated, and few suggestions have been made to the contrary, segregation will simply hold title to mineral in abeyance until some one is ready to develop the mineral resources of the tract. Then this right too may be alienated if desired. In the event of a person acquiring title to a piece of land which he has reason to believe will some day, by reason of its geographical location, control an important industry and become very valuable, I thoroughly believe that he and his heirs or assigns are wholly entitled to the so-called unearned increment because of the man's foresight. Should he spend his fortune to develop this property, he is so much more entitled to the increased value. Regardless of the success or failure of his surface development, should it subsequently be discovered that he had located on a valuable diamond pipe, an important iron or fuel deposit, and that he had suddenly become wealthy because of this discovery, it must certainly be regarded as an unearned increment to which he has no just right.

In the mining and treatment of precious metals it is customary to use a great deal more surface than corresponds to the area underlain with

useful vein matter. The operator needs a place for his mining and milling plant, his tailings, and dwellings. Sometimes he requires additional surface because of the timber that grows upon it. In other words, when a man works a vein, he needs all the surface included in his claim and more too. From which it might be suggested that the surface rights should not be separated from underground rights in the case of precious metals, lead, copper, and zinc. In the past this need of surface rights has caused the prospector to locate much more ground than he really required, locating and holding it as mineral claims, doing no work to benefit its mineral possibilities, and really securing title to it through a technical fraud. Or if he has not done this, he has been forced to buy his neighbors' claims at mine prices, just to secure surface rights. Were the two kinds of rights separated, each and as much of each as was desired could be purchased or acquired without technical fraud, and often the desired surface rights could be more favorably located than if the prospector were allowed to take only those within the boundary of his mineral claim.

A very few objections have been offered to segregation. Of 61 mining men who have expressed an opinion on the subject, I note that 7 are undecided, 15 are opposed to it, and 39 are in favor of it. Very few of those who are opposed to segregation have given any reason except that they believe it impracticable; some suggest that there will be a confusion of ownership. Theoretically this may be the case. In practice it has been found that the owner of mineral rights has generally been able to acquire all surface rights required for construction and operating purposes, and generally these have been acquired direct from the surface owner more quickly and on better terms than by acting through the government, even though there existed government machinery for the purpose.

Some have contended that it is impossible to segregate all minerals from surface rights, taking as examples Mesabi iron ores, the Pennsylvania cement limestones, and the clay banks everywhere which may some day be mined for aluminum. That the mining of any one of these substances will involve the destruction of the surface over the body worked, must be admitted; but it does not follow that because of these exceptions we must always treat the surface and its underground resources as one and the same thing. If a man desires to mine iron ore or quarry limestone or slate, there is nothing in the segregation idea to prevent him from getting all of the land he wants.

If it is desired to allow ownership of land to include ownership of superficial non-metallic substances, as in Australia, this, it has been found, can be done without any complications whatever.

About all of the objections offered to segregation suggest that the objectors do not want to see a change made for fear that some unforeseen trouble may arise. But segregation is not an experiment. Mineral

rights, water rights, and timber rights have been recognized as distinct from agricultural rights in many lands, for many years. Canadian Provinces and Australian States have conducted their affairs under laws which did not segregate and did alienate, and they have also worked under laws where segregation was followed and lands were sold, or leased, or operated for the production of that with which nature had endowed them. Mismanagement has at various times attended the administration; but the tendency that has been most beneficial has been toward more governmental control, and not less. In these countries there will be no return to the practice of selling everything within given boundaries, regardless of what may be there, and for what it may be useful.

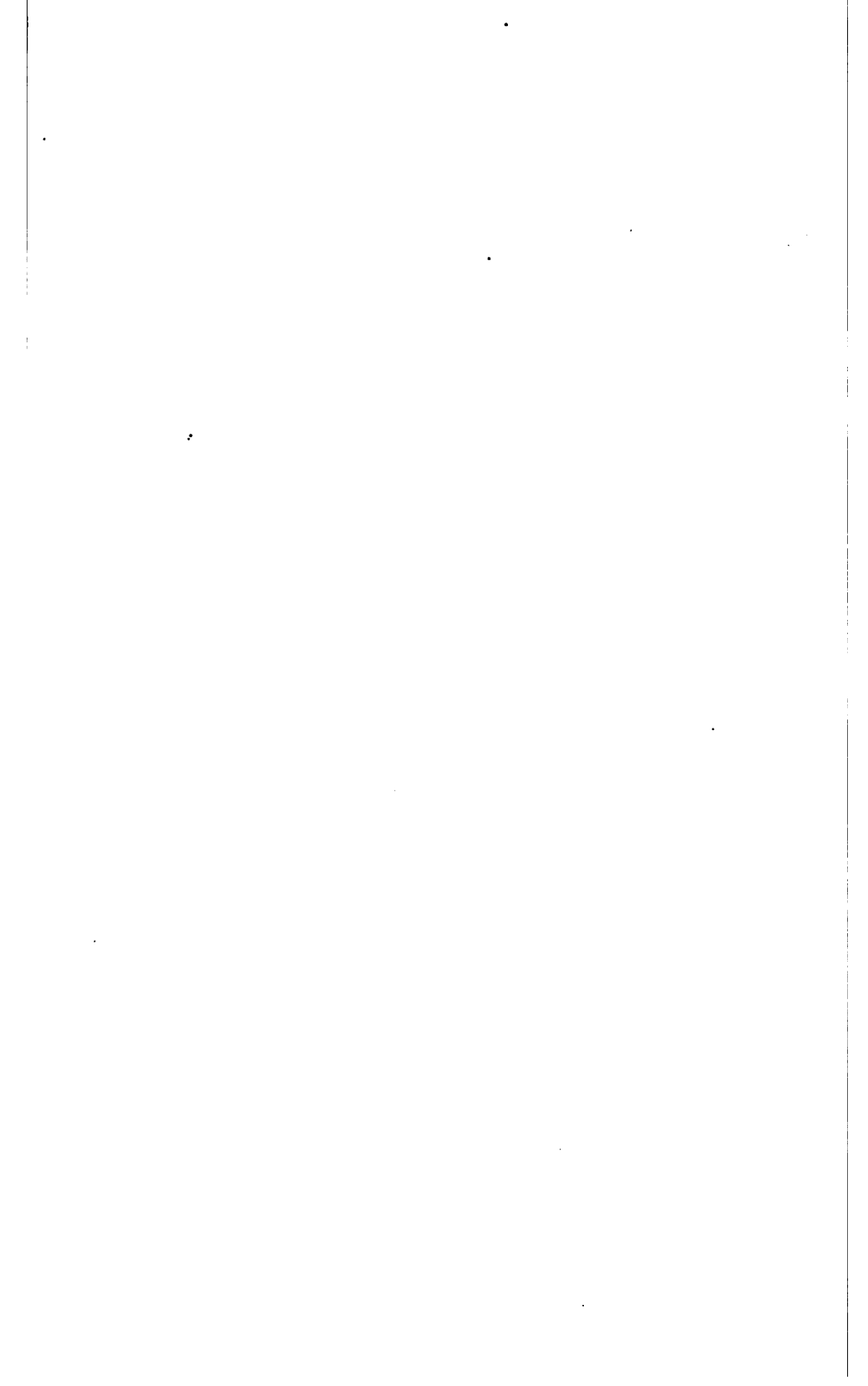
In nearly all of the Provinces of Canada, there are three distinct rights in every parcel of land, timber rights, mineral rights, and agricultural rights. In some instances these rights are all held by one individual or corporation; in others they are held by three different ownerships. The miner is at some disadvantage, for he is only entitled to cut such timber as he requires for his buildings; but he can buy stumpage at a nominal rate and does not go through the farcical scheme of making mineral locations and doing assessment work just to hold timber. Under the above arrangement, the miner, unless he buys surface and timber rights, does at times find himself in conflict with the timber and land owner, but it is not a serious conflict; and as the mineral is apt to be of greater temporary importance than the other rights, the miner appears to be somewhat favored.

In Australia, the segregation of surface from mineral rights has been the custom in most of the colonies for many years. There a person who has obtained title to a piece of land for cultivation, building, or other improvement, is presumed to have taken it up for that purpose only, and not for the unknown natural resources that it may ultimately prove to hold. The State does not reserve all values, such as the unearned increment due to some peculiar geographical position, proximity of railways or power plant, etc., nor does it retain surface deposits of clay, slate, lime, etc. These are conveyed with the surface rights.

In practical operation, it has been found easier and simpler to make an arrangement with the owner of surface rights to work on his ground than it has been to get that right through the government by any condemnation proceedings. The great advantage in Australia has been that it has thrown any and all land open to agricultural location without interfering with the rights of the prospector, both of which have been of prime importance in the development of that country. And the tendency is rather toward restricting the rights of the land owner, making conditions easier for the prospector of minerals.

While segregation of surface from mineral rights would not cure all existing difficulties connected with our present mining laws, it would,

because of the very different nature of these rights, simplify the application of remedies. The Federal government could encourage the development of the surface or of the underground portion, without sacrificing the interest of the public in that feature which is not to be immediately developed. The immediate necessity of classification with attending expense and uncertainty would be avoided, and the application of certain laws to certain classes of mineral substances could be deferred until the mineral was discovered. The regulation of surface and mineral rights could be enforced without serious conflict. In short, segregation will conserve our mineral resources for those who wish to develop them, and the lands will be held in such shape that appropriate laws may be enforced without detriment to those not interested in mining.



DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at a meeting of the Institute. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y.

Safeguarding the Use of Electricity in Mines

BY H. H. CLARK, CHICAGO, ILL.

(New York Meeting, February, 1914)

ELECTRICITY must be safeguarded everywhere that it is used. The conditions that exist underground make the use of safeguards more essential there than almost anywhere else.

Electric Shock

Electric shock is the greatest danger in connection with the use of electricity in mines, because conditions existing underground are so favorable to its occurrence. Men are often obliged to work in more or less uncertain light near bare wires that are carrying dangerous potentials. The fact that the men are standing on the earth practically connects them to one terminal of the electric generator.

The most dangerous piece of electrical equipment underground is the trolley wire. It is necessarily bare and extends for long distances throughout a mine, often less than a man's height from the track rail. Sometimes the making up of trips of cars must be done near low-hanging trolley wires. All bare wires offer the same danger that trolley wires do, although not to the same extent.

Apparatus that has accidentally come in contact with the ungrounded side of an electric circuit is almost as dangerous as the trolley wire. A severe and even fatal shock may be obtained by coming in contact with the frame of a motor or a switch box that has become charged with electricity, or "alive," as it is usually termed. It is also possible to obtain shocks from the frames of locomotives and cars if track sanding, poor bonding or a similar cause has put a high resistance to earth in the path of the current.

Fires Caused by Electricity

The danger from fires caused by electricity arises principally from defective installation and careless upkeep or from injuries to equipment resulting from falls of roof or similar causes. Fires may be started by unrelieved short circuits, or grounds, by the blowing of open fuses, and

by the overheating of resistances. Incandescent lamps can produce heat enough to ignite combustible materials if the dissipation of the heat from the bulbs of the lamps is allowed to become restricted. The fire danger is more remote than the shock danger, but it may affect a larger number of men.

Explosions Caused by Electricity

Explosions may be caused by the ignition of explosives, gas, or coal dust. Accidents due to the ignition of explosives by electricity are of two kinds: Those that occur while handling and transporting explosives near electric circuits, and those that are incident to the detonation of explosives by electrical means.

Transporting Explosives.—Some very mysterious accidents of the first kind have occurred, but I believe that most of these have been caused by hauling explosives in metallic packages, or else so near the locomotive that flashes or sparks from the trolley wire have come in contact with the explosives.

Electrical Shot-Firing.—Electrical shot-firing accidents are usually caused by the premature ignition of shots after holes are charged. It is not the best practice to shoot electrically under conditions that require one side of the detonating circuit to be connected to the earth, because wherever grounded systems of power distribution are used unexpected differences of potential exist in the earth in the vicinity of such circuits. If, therefore, one side of the detonator be purposely grounded an accidental ground on the other side may connect the detonator across a potential sufficient to cause ignition. Premature ignitions have been reported which seemingly have been caused by the conditions just described.

Gas Ignition by Electricity

For all practical purposes it may be assumed that sparks that occur around such apparatus and circuits as are used for power and light in a mine are capable of igniting gas. The ignition of gas by incandescent lamps has been investigated by the Bureau of Mines quite thoroughly with carbon filament lamps and to a lesser extent with tungsten filament lamps. The results of the investigation seem to indicate that certain of the larger sizes of carbon filaments will ignite gas and that tungsten lamps of 25 watts or more are almost certain to ignite gas when broken.

Ignition of Coal Dust by Electricity

The study of the ignition of coal dust by electric arcs and electric flashes has been carried on to some extent by investigators in Europe. The results of their experiments indicate that electric flashes can ignite

coal dust suspended in the atmosphere. The Bureau of Mines has planned similar investigations to proceed as soon as funds are available.

Underground Conditions are Favorable to the Occurrence of Accidents

Every one connected with mining work knows that the natural conditions surrounding underground installations of any character are such that accidents are likely to occur and this is especially true of electrical installations. It is not necessary to rehearse all of these conditions, as every one is familiar with them.

Prevention of Electrical Accidents

The knowledge of the existence of danger requires that steps be taken to prevent accidents. It is certain that haphazard methods will not solve the safety problem any more than they will solve the haulage problem or the ventilation problem. Measures to be effective must be well considered.

Unfortunately, the safety problem cannot be solved on just the same basis as the ventilation problem, for instance. Safety cannot be calculated mathematically by the use of constants obtained from experience. Definite data as to what will produce safety under the complex conditions involved are not available. It has seemed to me that a good way to begin is to outline methods that, so far as we can see, will surely produce safety, and then to determine how these methods can be put into practical operation. For the sake of discussion, therefore, I will make the following five suggestions for reducing the number of accidents due to the use of electricity in mines:

1. Remove contributory causes.
2. Remove from the vicinity of electrical apparatus all elements susceptible to its influence (gas, dust, explosives, combustible material).
3. Keep the electric current where it belongs.
4. If, under certain circumstances, the current cannot be entirely confined, at least limit the area of its activity by the use of protective devices.
5. Insure a high factor of safety by:
 - (a) Selecting materials and apparatus with care.
 - (b) Installing equipment in a strictly first-class manner.
 - (c) Inspecting equipment frequently and thoroughly.
 - (d) Maintaining it in good condition at all times.

Concerted Action

Suppose that it is agreed that these measures (or any others) will solve the problem, the next question is how to put these into effect. To get the best results the co-operation of all concerned must be secured.

There may be, no doubt there will be, many ways of getting the desired result. Each one has his own experience and his own views based thereon, but disorganized forces acting along different lines will not produce the results of concerted action along lines that, in the light of combined experience, may be agreed upon by the majority of those interested. The greatest benefit can be derived if, from the great mass of experience of the many who are interested in safeguarding electricity in mines, a definite plan of common action can be evolved and a code of rules laid down, which in the opinion of all will bring about the safe conditions that all desire. If such a code were put into effect generally, its weak points could be strengthened from time to time by the common experience of many engineers and operators, who would be trying out the same requirements under various conditions.

Co-operation of Mine Electricians

My experience and that of others reported to me leads me to believe that a code of rules would be welcomed by the underground electrical men who are to put them in force. These men, as a whole, desire to do things in the proper way and would be glad to have the proper way pointed out to them. They enjoy arbitrary criticism as little as any one, but I believe that most of them would appreciate constructive criticism and would co-operate in carrying out suggestions made by people in whom they have confidence. If such a movement could be started its difficulties would grow less as time went on, because the power of tradition is nearly as strong for good as it is for evil. The average electrical worker on the surface knows how to install electrical apparatus, because he has been educated and guided by the Underwriters' rules which have established a tradition for good work which cannot lightly be set aside.

I wish to emphasize that the solution of this problem rests largely with the underground electrical worker. If good men are selected for this position and are properly instructed and encouraged to look out for the safety side of the electrical work, the problem is practically solved.

Electricity as a Safeguard

I believe that we shall see the day when electricity, so far from being considered a menace to those who work in mines, will be regarded as a means of safeguarding life and property and reducing the accidents that heretofore have occurred. Already there are certain electrical devices whose adoption and general use will make for safety. Among these are the telephone, the electrical shot-firing device, the storage-battery locomotive, and portable electric mine lamps. If the storage-battery locomotive can be developed so that it can successfully displace the trolley-

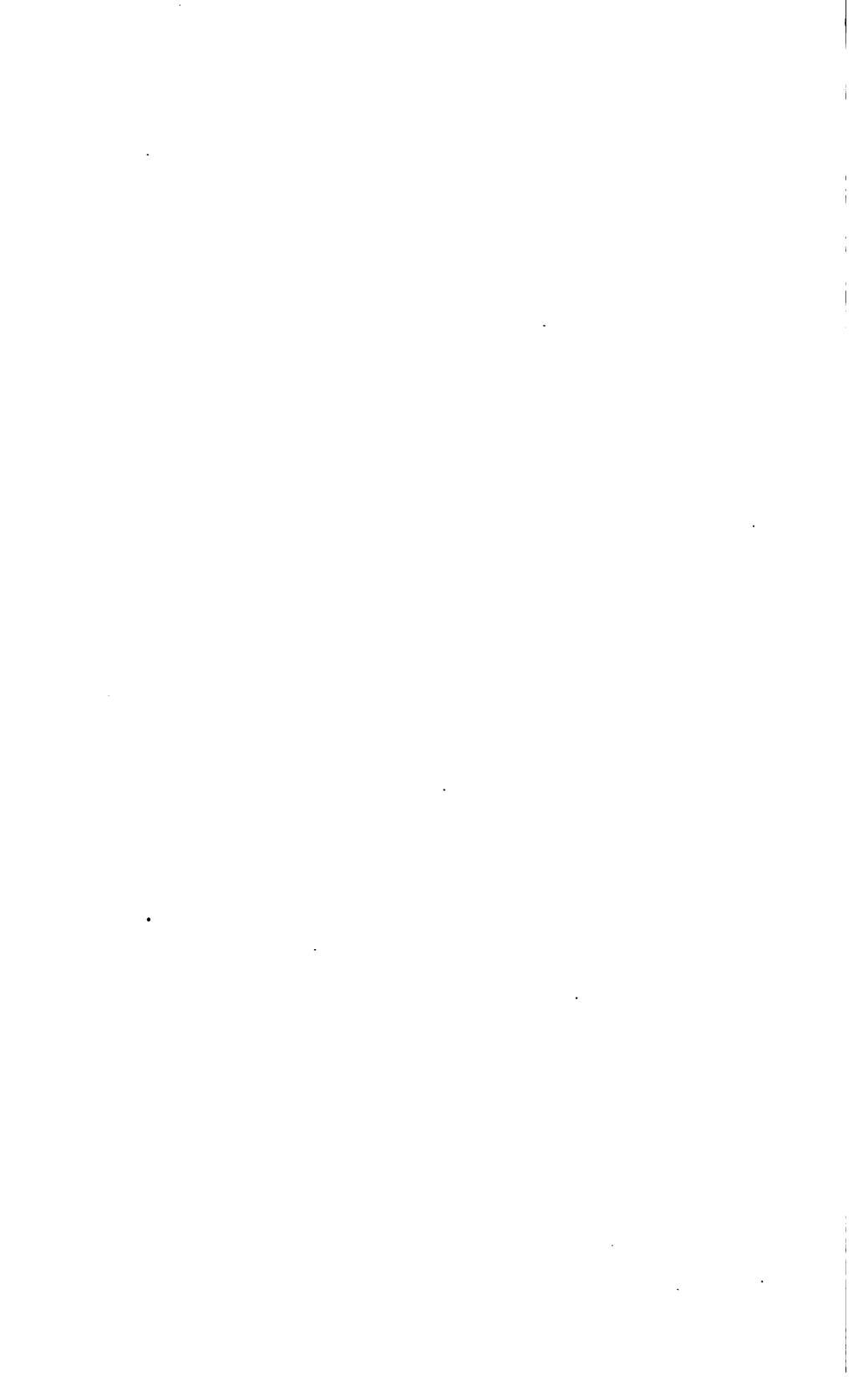
wire locomotive, the greatest single cause of electrical accidents, the trolley wire, can be withdrawn from service at least to a large extent.

Portable Electric Lamps.—The engineers of the Bureau of Mines and other engineers believe that the use of portable electric lamps will do much toward reducing the number of accidents in mines, and with this in mind we are making every effort to assist in the development and urge the adoption of these lamps. Based upon the undoubtedly true premise that the battery is the part of a portable lamp equipment most difficult to develop, there has been a tendency to lose sight of certain other necessary features of portable electric lamps. The first consideration in the design of these lamps is to have them safe so that they will not ignite gas and so that they will not become extinguished and leave a man in the dark, but while these points are indispensable it is equally important that the lamps shall be designed so that they will be acceptable to the men who are to carry them.

Portable electric lamps must be a compromise between several more or less opposed requirements. The fundamental considerations of lamp capacity are the maximum allowable weight of battery, the minimum allowable amount of light, the minimum allowable time of burning, and the minimum allowable life of lamp bulbs. These factors are all interdependent and must be properly proportioned in order to produce an acceptable net result. Other factors must also be kept in mind. Bitter experience with gas explosions led the early English miners to abandon the comparatively brilliant light of the torch for the feeble phosphorescence of fish scales and the scarcely less feeble scintillations of the steel mill. While our modern, ventilated coal mines are probably much less gassy than the unventilated mines of the thirteenth century, nevertheless safety is just as essential now as it was then, and it has been proved that miniature electric lamps can ignite gas if broken under certain conditions obtainable in practice. Therefore, portable electric lamps should be provided with proper safeguards.

Acting upon the principle that the greatest progress can be made by common efforts to the same end, the Bureau has attempted to further the cause of the portable electric lamp by acting as a sort of "go-between" for the miners and the manufacturers in the work of preparing specifications that will represent the kind of lamp that will give the service required by the miners. I wish here to acknowledge the great assistance that the manufacturers have given to the Bureau, and to state that they have at all times manifested that spirit of co-operation without which progress is impossible.

The Bureau would also like the co-operation of this Institute in the matter of examining and criticising these specifications, which will be sent to any member interested.



APRIL 1, 1914

(Corrected to March 1, 1914)

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*Coal and Coke*H. M. CHANCE, *Chairman.*SAMUEL D. WARRINER, *Vice-Chairman.* SAMUEL A. TAYLOR, *Vice-Chairman.*
FREDERICK W. C. WHYTE, *Vice-Chairman.*ELI T. CONNER, *Secretary*, 1126 Real Estate Trust Bldg., Philadelphia, Pa.

FRANKLIN BACHE,	GEORGE W. EVANS,	WILLIAM N. PAGE,
SAMUEL W. BEYER,	HENRY S. FLEMING,	FLOYD W. PARSONS,
WILLIAM H. BLAUVELT,	FRANK HAAS,	EDWARD W. PARKER,
FRED M. CHASE,	FRANK A. HILL,	EDGAR P. PETTEBONE,
CLARENCE R. CLAGHORN,	CHARLES F. HUBER,	ERKSINE RAMSAY,
EDWARD H. COXE,	ALBERT B. JESSUP,	GEORGE S. RICE,
JAMES S. CUNNINGHAM,	CHARLES E. KREBS,	W. J. RICHARDS,
FRANK W. DeWOLF,	EDWIN LUDLOW,	CARL SCHOLZ,
A. W. DICKINSON,	MARSHALL G. MOORE,	HARRY H. STOEK,
HOWARD EAVENSON,	R. V. NORRIS,	MORRIS WILLIAMS.
CHARLES EZNIAN,	THOMAS H. O'BRIEN,	

*Mining Law*HORACE V. WINCHELL, *Chairman.*CORNELIUS F. KELLEY, *Vice-Chairman.* CURTIS H. LINDLEY, *Vice-Chairman.*JOHN W. FINCH, *Secretary*, 730 Symes Bldg., Denver, Colo.

ALBERT BURCH,	JOSEPH A. HOLMES,	WILLIAM SCALLON,
WILL L. CLARK,	EDWIN O. HOLTER,	C. H. SHAMEL,
C. LORIMER COLBURN,	EDWARD B. KIRBY,	FRANK L. SIZER,
COURTENAY DeKALE,	MARK L. REQUA,	JOEL F. VAILE,
CHARLES W. GOODALE,	GEORGE W. RITER,	WALTER H. WILEY.
FREDERICK T. GREENE,		

*Petroleum and Gas*ANTHONY P. LUCAS, *Chairman.*WILLIAM N. BEST, *Vice-Chairman.* DAVID T. DAY, *Vice-Chairman.*WILLIAM B. PHILLIPS, *Vice-Chairman.* MARK L. REQUA, *Vice-Chairman.*LEONARD WALDO, *Secretary*, 49 Wall St., New York, N. Y.

RALPH ARNOLD,	C. WILLARD HAYES,	WALTER O. SNELLING,
FREDERICK G. CLAPP,	PHILIP W. HENRY,	WILLIAM L. WATTS,
EUGENE COSTE,	HANS VON HOEFER,	H. A. WHEELER,
EDWIN T. DUMBLE,	ISAAC N. KNAPP,	WILLIAM A. WILLIAMS.
JOHN R. EDWARDS,	EZEQUIEL ORDONEZ,	

*The Use of Electricity in Mines*WILLIAM KELLY, *Chairman.*FRANCIS O. BLACKWELL,
CHARLES W. GOODALE,
MAX HEBGEN,
JOHN LANGTON,
THOMAS H. LEGGETT,
FREDERICK W. O'NEIL,
DAVID B. RUSHMORE.

PAST OFFICERS

PRESIDENTS

*DAVID THOMAS	1871
R. W. RAYMOND	1872-1874
*A. L. HOLLEY	1875
*ABRAM S. HEWITT	1876
*T. STERRY HUNT	1877
*ECKLEY B. COXE	1878-1879
*WILLIAM P. SHINN	1880
*WILLIAM METCALF	1881
*RICHARD P. ROTHWELL	1882
ROBERT W. HUNT	1883
*JAMES C. BAYLES	1884-1885
ROBERT H. RICHARDS	1886
*THOMAS EGLESTON	1887
WILLIAM B. POTTER	1888
RICHARD PEARCE	1889
*ABRAM S. HEWITT	1890
JOHN BIRKINBINE	1891-1892
H. M. HOWE	1893
*JOHN FRITZ	1894
*J. D. WEEKS	1895
E. G. SPILSBURY	1896
*THOMAS M. DROWN	1897
CHARLES KIRCHHOFF	1898
JAMES DOUGLAS	1899-1900
E. E. OLCOTT	1901-1902
ALBERT R. LEDOUX	1903
JAMES GAYLEY	1904-1905
ROBERT W. HUNT	1906
JOHN HAYS HAMMOND	1907-1908
D. W. BRUNTON	1909-1910
CHARLES KIRCHHOFF	1911
JAMES GAYLEY (Corporation)	1905-1911
JAMES F. KEMP (Council and Corporation)	1912
CHARLES F. RAND	1913
BENJAMIN B. THAYER	1914

SECRETARIES

*MARTIN CORYELL	1871-1872
*THOMAS M. DROWN	1873-1884
R. W. RAYMOND	1884-1911
JOSEPH STRUTHERS	1911-1912
BRADLEY STOUGHTON	1913 —

TREASURERS

J. PRYOR WILLIAMSON	1871-1872
*THEODORE D. RAND	1873-1902
FRANK LYMAN	1903-1912
GEORGE C. STONE	1913 —

OFFICERS OF THE INSTITUTE FROM 1871 to 1914, Inclusive.

P, President; PD, President of Board of Directors; PP, Past President; V, Vice-President; VD, Vice-President of Board of Directors; M, Manager; S, Secretary; SD, Secretary of Board of Directors; S. Em, Secretary Emeritus; a, Assistant Secretary; T, Treasurer; t, Assistant Treasurer; D, Director; C, Councilor; E, Editor; and e, Assistant Editor;

ALEXANDER, JOHN S., M., '74-6, '81-3.	CARLTON, ALBERT E., C., '11-12.
ASHBURNER, C. A., M., '85-7.	CHAMBERLAIN, H. S., V., '96-7.
ASMUS, GEORGE, M., '78-80.	CHANNING, J. FARKE, V., '08-9.
BACON, D. H., M., '00-2.	CHRISTY, S. B., V., '91-2, '07-8, '11-12.
BAYLES, JAMES C., M., '80-2, '913; P., '84-5; V., '88-9.	CHURCH, JOHN A., M., '79-81, '94-6; V., '07-8.
BIRKINBINE, JOHN, M., '83-5; V., '87-8; P., '91-2.	COGBWELL, W. B., V., '74-5, '86-7.
BLAIR, THOMAS S., M., '74-6.	COLE, THOS. F., V., '05-6.
BLAKE, WILLIAM P., V., '71-4, '76-7, '05-6.	COOK, EDGAR S., M., '84-6.
BLANDY, JOHN F., V., '71-3, '78-9.	CORNING, C. R., C., '08-9.
BLOW, A. A., C., '05-7.	CORYELL, MARTIN, S., '71-2; M., '73-5.
BOWIE, A. J., JR., V., '93-4.	COX, E. T., M., '77-9.
BRAMWELL, J. H., M., '89-91.	COXE, ECKLEY B., V., '71-4, '76-7, '84-5, '89-90;
BROCK, REGINALD W., D., '14.	P., '78-9.
BROOKS, THOS. B., M., '72.	COXE, WM. E. C., M., '79-81, '85-7.
BRUNTON, D. W., V., '97-8; P., '09-10.	CROCKER, G. A., M., '01-3.
BUCK, STUART M., M., '83-5.	DAY, D. T., V., '92-3, '00-1.
BURDEN, JAMES A., V., '80-1.	DELANDERO, C. F., V., '02.
BURNHAM, WILLIAM, M., '82-4.	DENTON, FREDERICK W., V., '08-9, '13-14.
CAMPBELL, H. H., M., '93-5.	DESALLUES, A. B., M., '87-9.

*Deceased.

- DEVEREUX, W. B., M, '98-00.
 D'INVILLIERS, E. V., V, '94-5; M, '00-2.
 DOUGLAS, JAMES, V, '97-8; P, '99-00; D, '05-13;
 VD, '06-11.
 DRINKER, HENRY S., M, '77-9.
 DROWN, THOMAS M., M, '72; S, '73-83; V, '92-3;
 P, '97.
 DUDLEY, CHARLES B., V, '80-81.
 DWIGHT, ARTHUR S., C, '09-10.
 DWIGHT, THEODORE, S, '95-05; t, '98-05; D, '06-11; C, '06-8.
 EGGLESTON, THOMAS, M, '71; V, '72-4, '77-8,
 '84-5; P, '87.
 ETLERS, ANTON, M, '75-7; '82-4; V, '96-7.
 EILERS, KARL, C, '09-11; V, '12-14.
 ELY, T. N., V, '82-3.
 EMMONS, S. F., V, '83-4, '90-1, '02-3.
 EUSTIS, W. E. C., V, '97-8.
 FACKENTHAL, B. F., JR., M, '87-9; C, '07-9.
 FARISH, JOHN B., V, '08-9.
 FEUSTMAN, L. P., V, '98-9.
 FINCH, JOHN W., D, '13-14.
 FIRMSSTONE, FRANK, M, '73, '84-6, '89-91; V, '75-6.
 FORTYTH, ROBERT, M, '80-00.
 FRAZER, PERSIFOR, V, '80-1, '07-8.
 FRAZIER, B. W., M, '74-6, '78-80.
 FRITZ, JOHN, V, 75; P, '94.
 FELTON, JOHN, V, '85-6.
 GAUJOY, E., M, '71-2.
 GATLEY, JAMES, M, '96-8; V, '02-3; P, '04-5;
 PD, '05-11; D, '05-13.
 GLENN, WILLIAM, M, '99-01.
 GOETE, GEO. W., M, '92-4; V, '01.
 GOODALE, C. W., M, '97-9.
 GRAMMER, F. L., M, '04; C, '05-6.
 GRANT, J. B., V, '96-7.
 HAGUE, JAS. D., V, '06-7.
 HAMMOND, J. H., V, '01-2; P, '07-8.
 HARDMAN, J. E., V, '01-2.
 HARTHORNE, JOSEPH, M, '04; C, '05-6.
 HEINRICH, OSWALD J., M, '75-7.
 HEWITT, ABRAHAM S., M, '72-5; P, '76, '90.
 HOPMAN, H. O., M, '94-6; C, '07-9.
 HOLBROOK, LEVI, M, '95-7.
 HOLLEY, A. L., V, '74; P, '75; M, '77-9.
 HOLLIS, H. L., M, '92-4.
 HOLLOWAY, J. F., V, '87-8, '94-5.
 HOLMES, JOSEPH A., D, '13-14.
 HOOVER, H. C., V, '14.
 HOWE, H. M., V, '79-80, '90-1, '06-7; M, '86-8;
 P, '93.
 HUMPHREYS, A. C., C, '09-11.
 HUNT, A. E., V, '88-9.
 HUNT, ROBERT W., M, '76-8; P, '83, '05-6;
 D, '13-14.
 HUNT, T. STERRY, M, '73-5; P, '77; V, '88-9.
 INGALLS, W. R., C, '07-9.
 JACKLING, D. C., D, '14.
 JANEWAY, JOHN H., JR., C, '12; D, '13-14.
 JENNINGS, HENNER, C, '12.
 JENNINGS, ROBERT E., C, '10-12.
 JENNINGS, SIDNEY J., C, '12; V, '13-14.
 JOHNSON, J. E., M, '86-8, '01.
 JONES, CLEMENS C., M, '02-3.
 KELLY, WILLIAM, C, '10-12.
 KEMP, J. F., M, '96-8; V, '03-4; D, '05-12; P,
 '12; PD, '12; PP, '13-14.
 KENNEDY, J., V, '04-5.
 KENT, JOSEPH C., V, '74-5.
 KENT, WILLIAM, M, '00-2.
 KERR, W. C., V, '83.
 KEYES, W. S., M, '80-2; V, '84.
 KIMBALL, J. P., V, '81-2.
 KIRBY, E. B., VD, '12; D, '13-14.
 KIRCHHOFF, C., M, '87-9, '92-4; V, '96-7; P, '98,
 '11; D, '07-12; PP, '12-13.
 KLEPETKO, FRANK, M, '03-4; C, '05; D, '05-6.
 KUNHARDT, W. B., V, '95-6.
 KUNE, GEO. F., V, '99-01.
 LATHROP, WILLIAM A., V, '11-12.
 LAWRENCE, B. B., M, '03-4; C, '05; V, '10-11.
 LECKIE, ROBT. C., V, '93-4.
 LEDOUX, ALBERT R., M, '95-7; V, '98-9; P, '03;
 D, '05-14.
 LEE, J. H., V, '02-3.
 LEGGETT, THOMAS H., V, '13-14.
 LESLEY, J. P., M, '72-4.
 LEWIS, JAMES F., M, '79-81; V, '86-7, '95-6.
 LINDOREN, WALDEMAR, V, '12-13.
 LYMAN, B. S., M, '96-8.
 LYMAN, FRANK, M, '97 9; T, '03 12; C, '05-6;
 D, '05-12.
 MACDONALD, CHARLES, V, '82-3, '89-90.
 MACKINTOSH, J. B., M, '91.
 MARKLE, JOHN, V, '03-4.
 MATHESON, E. P., D, '13-14.
 MAYNARD, GEORGE W., M, '71-4, '85-6; V, '04-5.
 MCCREATH, ANDREW S., M, '82-4.
 MCNAIR, T. S., M, '71, '84.
 MERRILL, CHARLES W., D, '14.
 METCALF, WILLIAM, V, '78-9; P, '81.
 MILLER, WILLET G., C, '09-11.
 MOEN, PHILIP W., V, '03-4.
 MOFFAT, E. S., M, '83, '85; V, '87, '89.
 MUNROE, H. S., M, '81-4; V, '90-1.
 NEILL, JAMES W., M, '02-4.
 NEILSON, W. G., M, '86-8.
 NEWBERRY, J. S., M, '78-8.
 NORRIS, R. V., C, '08-10; V, '11-12.
 OLCOTT, E. E., P, '01-2.
 OLCOTT, W. J., M, '98-00; C, '11-12; D, '13.
 PAGE, W. N., V, '99-00.
 PARKER, E. W., M, '02-4.
 PEARCE, RICHARD, V, '85-6; P, '89.
 PEARSE, JOHN B., V, '77-8.
 PECHIN, E. C., M, '72; V, '73, '75-6, '85, '91-2.
 PETERS, E. D., JR., V, '98-9.
 PETHERICK, THOMAS, M, '71-2, V, '84.
 PETTEE, WM. H., M, '73, '89-91; V, '81-2.
 PLATT, J. C., V, '94-5.
 PORTER, J. A., M, '91-3.
 POTTER, E. C., V, '99-00.
 POTTER, WILLIAM B., M, '78-80; P, '88.
 POWELL, J. W., V, '82-3.
 PRIME, FRED., JR., M, '71-3.
 PUMPELLY, RAPHAEL, M, '71.
 RALSTON, W. C., V, '00-1, '09-10.
 RAND, CHARLES F., C, '10-12; D, '12; P, '13;
 PP, '14.
 RAND, THEODORE D., T, '73-02.
 RANDOL, J. B., V, '00-1.
 RANDOLPH, J. C. F., M, '81-3; V, '91-2.
 RAYMOND, R. W., V, '71, '76-7; P, '72-4; S, '84-11;
 S, Em, '11-14.
 RICHARDS, JOSEPH W., V, '10 11; C, '12; D, '13-14.
 RICHARDS, ROBERT H., V, '79-80; P, '86.
 RICKARD, T. A., M, '94-6; D, '05; C, '05-6.
 RICKETTS, L. D., D, '13-14.
 RIES, HEINRICH, M, '03-4; C, '05.
 ROBERTS, PERCIVAL, JR., M, '80-2; V, '89-90.
 ROBERTSON, KENNETH, M, '88-90.
 ROBERTSON, WM. F., C, '06-8.
 ROBINSON, C. S., D, '13.
 ROLKER, C. M., M, '89-90.
 ROTHWELL, RICHARD P., M, '71, '98-00; V, '72-3,
 '75-6; P, '82.
 SAUNDERS, W. L., V, '09-10, '14.
 SAUVEUR, ALBERT, V, '10, '11.
 SHEAFER, W. L., M, '93-5.
 SHINN, WILLIAM P., V, '77-8; P, '80.
 SHOCKLEY, WILLIAM H., C, '08-10.
 SHOOK, A. M., M, '93-5.
 SMOCK, JOHN C., M, '75-7, '91-3.
 SMYTH, HENRY L., D, '14.
 SNOW, CHAS. H., M, '04; C, '05-6; D, '05-10.
 SPILSBURY, E. G., M, '85-7; V, '93-4; P, '96.
 STANTON, F. McM., M, '97-9.
 STANTON, JOHN, V, '92-3.
 STEARNS, I. A., V, '05-6.
 STEFFELDT, C. A., V, '85-6, '95-6.
 STONE, G. C., SD, '12; D, T, '13-14.
 STOUGHTON, BRADLEY, S. E., '13-14.
 STRUTHERS, J., e, '03-5; s, '06-10; t, E, '06-12;
 D, '11; S, '11-12.
 SWOYER, J. H., V, '71.
 SYMONS, W. R., V, '71-2; M, '73-4.
 TAYLOR, W. J., M, '90-2, '99-01.
 THAYER, BENJAMIN B., V, '12-13; P, '14.
 THOMAS, DAVID, P, '71.
 THOMAS, SAMUEL, V, '79-80.
 THOMPSON, CHARLES O., V, '81-2.
 THURSTON, ROBERT H., V, '78-9.
 VALENTINE, M. D., M, '02-4.
 WALCOTT, C. D., V, '04-5.
 WALKER, ARTHUR L., D, '11.
 WEBSTER, WILLIAM R., M, '95-7.
 WEEKS, J. D., V, '86-7; M, '90-2; P, '95.
 WELLMAN, S. T., V, '83-4; M, '90-2.
 WILLIAMS, GARDNER F., V, '11-12.
 WILLIAMS, T. M., M, '71.
 WILLIAMSON, J. FRYOR, T, '71-2.
 WINCHELL, H. V., M, '01-3; V, '09-10.
 WINSLOW, A., M, '99-01.
 WITHERBEE, THOS. F., M, '76-8.
 WOOD, WALTER, C, '06-8.
 YOUNG, EDWARD L., C, '11-12; D, '13-14.

INSTITUTE ACTIVITIES FOR THE YEAR 1913

Meetings of the Institute

Three meetings of the Institute for the presentation and discussion of technical papers were held in 1913: The 104th meeting, comprising the Annual Business Meeting as well as technical sessions, was held at New York, Feb. 18 to 20, 1913; the 105th meeting was held at Butte, Mont., Aug. 16 to 21, 1913, at which papers obtained largely through the efforts of the Committee on Precious and Base Metals were presented; and the 106th meeting was held at New York, Oct. 16 and 17, 1913, under the auspices of the Iron and Steel Committee.

Local Sections

In 1913, five local sections were established, as follows: St. Louis, Southern California, Colorado, San Francisco, and Montana. The Institute now has nine local sections.

Committees

Seven technical committees were formed in 1913, on the following topics:

Use of Electricity in Mines,
Mining Geology,
Mining Methods,
Mining Law,
Petroleum and Gas,
Non-Metallic Minerals,
Coal and Coke.

This makes a total of nine technical committees.

A committee on Increase of Membership and a committee on Junior Members and Affiliated Student Societies were also formed in 1913.

Affiliated Student Societies

The Mining Society of Pennsylvania State College, State College, Pa., an undergraduate organization, was recognized as an Affiliated Student Society in 1913. The total number of societies thus enrolled is 24.

Publications

Transactions.—Volumes XLIII and XLIV, containing the papers and discussions at the meetings held in 1912, were distributed in 1913.

The Emmons Volume was also published in 1913.

Bulletin.—The *Bulletin*, which was issued regularly throughout the year 1913, contained 2,816 pages of technical papers and discussions, as compared with 1,588 pages in 1912; 436 pages of announcements, etc., in the preliminary section, and 294 pages of advertising matter; making a total of 3,546 pages of printed matter as compared with 2,253 pages in 1912.

Membership

The total membership of the Institute on Jan. 1, 1914, was 4,150, as compared with 4,265 on Jan. 1, 1913. During 1913, 426 were added to the membership, as follows: 1 honorary member, 355 members, 31 associates, and 39 junior members. Against this should be recorded the deaths of 49 members and 1 associate; the resignation of 68 members and 9 associates; and the dropping from the rolls, for non-payment of dues, of 403 members and 11 associates—a total of 541. The unusual number dropped was due to the Constitutional provision requiring all members to be dropped who are one year in arrears of dues.

Co-operation with Other Organizations

The Institute was represented by delegates at the following conventions:

Canadian Mining Institute, March 5, 6, 7, 1913.

Twelfth International Geological Congress, Canada, Aug. 7–14, 1913

American Mining Congress, Philadelphia, Pa., Oct. 20–24, 1913.

Fifth National Conservation Congress, Washington, Nov. 18–20, 1913.

Safety and Sanitation Congress, New York, N. Y., Dec. 10, 11, 12, 1913.

The International Engineering Congress of 1915 is to be held in connection with the Panama-Pacific Exposition, under the joint auspices of the American Society of Civil Engineers, the American Society of Mechanical Engineers, the American Institute of Electrical Engineers, the Society of Naval Architects and Marine Engineers, and the American Institute of Mining Engineers.

Committee on Papers and Publications

The number of papers brought before the Committee was 183. Many were received from technical committees and these were mostly accepted: 20 were rejected, 4 were withdrawn by their authors, and 3 were returned to authors and not received again; 60 papers were presented at the Butte

meeting, 24 were presented at the New York meeting, October, 1913, and 64 were approved for presentation at the New York meeting, February, 1914; 8 are on hand for a subsequent meeting.

Employment Department

The Employment Department was started in March, 1913, and has already shown its importance as one of the Institute's activities. The work of this Department consists in publishing each month in the *Bulletin* a list of vacant positions which have come to the attention of the Secretary; also notes concerning the qualifications and desires of such members as are open for engagement. In addition to this, members on the list of Engineers Available are informed promptly of any openings which might be of interest, and every endeavor is made to bring employer and employee together.

This method has been the means of supplying employers promptly with desirable men for vacant positions and has helped many members to secure advantageous connections.

No charge is made for this service, since the Institute considers it a privilege and a duty to help its members, whether they are employers, or engineers in search of positions.

Statement of Assets and Liabilities

Dec. 31, 1913

<i>Assets</i>			
Current Assets:			
Cash			
In banks.....	\$2,832.54		
On hand.....	50.00	\$2,882.54	
Accounts Receivable:			
Advertising.....	\$1,431.40		
Miscellaneous.....	947.25	2,378.65	\$5,261.19
Invested Assets:			
Equity in United Engineering Society Building.....	\$353,346.62		
Equity in United Engineering Society Land.....	180,000.00		
Library.....	40,000.00	573,346.62	
			\$578,607.81
<i>Liabilities</i>			
Current Liabilities:			
Accounts Payable.....		\$10,655.04	
Deferred Liabilities:			
Mortgages Payable.....		34,000.00	
Reserve for Life Memberships.....		40,000.00	
Total Liabilities and Reserve.....		\$84,655.04	
Balance—being Excess of stated Assets over stated Liabilities.....		493,952.77	
			\$578,607.81

Statement of Receipts and Disbursements

Jan. 1 to Dec. 31, 1913

	Annual Dues	Initiation Fees	Life Membership	Total
Receipts from Dues, etc.				
Current.....	\$35,293.42	\$3,010.00	\$900.00	\$39,203.42
Arrears.....	2,246.44	.....	.....	2,246.44
In Advance.....	1,567.39	880.00	.....	2,447.39
Total.....	\$39,107.25	\$3,890.00	\$900.00	\$43,897.25
Receipts from other sources:				
Sale of <i>Transactions</i>			\$1,548.43	
Binding <i>Transactions</i>			6,528.86	
Sale of Author's Pamphlets.....			445.38	
Sale of other publications.....			2,930.52	
Sale of electrotypes.....			39.71	
Advertising in <i>Bulletin</i>			7,951.45	
Rent:				
Sub-rent from United Engineering Society, Rooms 901, 903, 917 and 918.....		\$2,128.00		
Sub-rent from G. F. Kunz, Room 915.....		120.00	2,248.00	
Miscellaneous:				
Land Fund.....			139.00	
Sundry.....			683.57	22,514.92
Total receipts for period.....				\$66,412.17
Cash in bank and on hand—January 1, 1913.....				7,350.91
				\$73,763.08
Disbursements:				
<i>Bulletin</i>	\$19,368.47			
<i>Year Book</i>	1,139.85		\$20,508.32	
<i>Transactions</i>			6,880.44	
Special Editions.....			2,839.69	
Editorial and office expense.....			25,940.59	
Treasurer.....			484.75	
Library.....			4,166.39	
Advertising.....			3,430.42	
Meetings.....			1,226.14	
Local Sections.....			826.60	
Technical Committees.....			426.56	
Miscellaneous.....			4,150.64	
Total Disbursements for period.....				\$70,880.54
Balance—being Cash in bank and on hand, Dec. 31, 1913:				
Fifth Avenue Bank of New York:				
Regular Account.....	\$2,175.04			
Special Account.....	250.76		\$2,425.80	
Brooklyn Trust Co.....			267.74	
National Bank of Commerce.....			139.00	
Petty Cash.....			50.00	\$2,882.54

MEMBERS, ASSOCIATES AND JUNIOR MEMBERS

THOSE MARKED THUS * ARE MEMBERS; MARKED THUS † ARE ASSOCIATES. THESE SIGNS DOUBLED INDICATE LIFE MEMBERS AND ASSOCIATES RESPECTIVELY. HEAVY-FACED TYPE SIGNIFIES HONORARY MEMBERSHIP. JUNIOR MEMBERS ARE MARKED J. THE FIGURES AT THE END OF THE ADDRESS INDICATE THE YEAR OF ELECTION.

- *AARONS, J. BOYD, Genl. Mgr., Chaffers G. M. Co., Boulder, West. Australia. '05
- *ABADIE, EMILE R., Min. Engr., Mutual Savings Bank Bldg., San Francisco, Cal. '76
- *ABBOTT, CLARENCE E., Genl. Supt., Iron Mines Div.,
Tennessee Coal, Iron & R. R. Co., Bessemer, Ala. '04
- *ABBOTT, JAMES W., Min. Engr., "St. Omer," 123 N. Grand Ave.,
Los Angeles, Cal. '94
- *ABBOTT, ROBERT R., Met. Engr., Peerless Motor Car Co., Cleveland, Ohio. '12
- ||ABRAHAMS, ALEXANDER I., Student.....67 E. 93rd St., New York, N. Y. '13
- †ACKER, E. O'C., Met.....Bethlehem Steel Co., Bethlehem, Pa. '86
- *ACKER, LOUIS K., JR., Min. Engr.....565 Highland Pl., Bellevue, Pa. '08
- *ADACHI, JINZOO.....No. 11 Shiba Park, Shiba-ku, Tokyo, Japan. '88
- *ADAMI, CHARLES J., Min. Engr.....Rivermines, Mo. '12
- *ADAMS, ARTHUR K., Min. Geol.....700 Mundy Ave., El Paso, Texas. '06
- *ADAMS, CHARLES W., JR., Smelting, American Smelting & Refining Co.,
Murray, Utah. '14
- *ADAMS, CUTLER, Prest. and Genl. Mgr., Cuyana & Iron Range Ry. Co.,
Deerwood, Minn. '05
- Adams, Dr. Frank Dawson, Logan Prof. of Geology and Dean Faculty of
Applied Science, McGill Univ., Montreal, Canada.
- *ADAMS, GEORGE I.....Prof. Geol., Pei Yang University, Tientsin, China. '01
- *ADAMS, HARRY C., Vice-Prest., Westmoreland Coal Co.,
224 So. Third St., Philadelphia, Pa. '03
- *ADAMS, HENRY, Min. Engr.....134 Lawn Ave., Stamford, Conn. '02
- *ADAMS, HUNTINGTON, Min. Engr.....Gante 8, Mexico City, Mexico. '03
- *ADAMS, MASON T., Min. Engr.....45 Broadway, New York, N. Y. '02
- *ADAMS, RALPH E., Asst. Supt., Velardeña Unit, Am. Smelters Securities Co.,
Velardeña, Dur., Mexico. '06
- *ADAMS, THOMAS J.....Rahway, N. J. '02
- *ADAMS, WALTER C., Min. Engr., 649 Roslyn Ave., Westmount, Que., Canada. '99
- *ADDICKS, LAWRENCE.....Chrome, N. J. '02
- *ADDIE, ROBERT, Min. Engr. and Met.,
Suffolk House, Laurence Pountney Hill, London, E. C., England. '98
- *ADIASSEWICH, ALEXANDER.....11 Nadejdinskaia, St. Petersburg, Russia. '14
- *AERTSEN, GUILLIAEM, Midvale Steel Co., P. O. Box 1606, Philadelphia, Pa. '88
- *AGABEG, EDGAR C., Cons. Min. Engr.,
Panuria P.O., via Sitarampore, E. I. Ry., Bengal, India. '05
- *AGNEW, FRANK VANS, Assayer, Care P. A. Vans Agnew, Kissimmee, Fla. '04
- ††AGNEW, GEORGE B.....22 William St., New York, N. Y. '03
- *AGNEW, JAMES C., Asst. Mgr., Mahoning Ore & Steel Co., Hibbing, Minn. '04
- *AGNEW, JOHN A., Min. Engr., Care Union Bank of Australia, Ltd.,
London, E. C., England. '09
- *AGNEW, JOHN L., Genl. Supt.....Copper Cliff, Ont., Canada. '14
- *AGNEW, WILLIAM C.....1925 E. 1st St., Duluth, Minn. '00
- *AGUILAR, PONCIANO, Min. Engr.....Sopefia 13, Guanajuato, Mexico. '01

- *AGUILERA, PEDRO, Cons. Engr.....Santiago de Cuba, Cuba. '05
- *AHBE, FREDERIC R., Min. Engr.....Athens, Pa. '97
- *AHLERS, RUDOLPH O., Min. Engr., Norfolk House,
Lawrence Pountney Hill, London, E. C., England. '99
- *AHLES, ROBERT L.....Sweets Steel Co., Williamsport, Pa. '02
- *ÅKERMAN, Prof. Richard.....34 Kungsgatan, Stockholm, Sweden.
- *ALDASORO, ANDRES, Min. Engr., Genl. Mgr., Dos Estrellas Min. Co.,
P. O. Box 34, El Oro, Mexico. '02
- *ALDEN, HERBERT W.....Mech. Engr., 33 Warren Ave. E., Detroit, Mich. '12
- *ALDERSON, VICTOR C.....615 Ideal Bldg., Denver, Colo. '13
- *ALDRICH, TRUMAN H., Postmaster.....Birmingham, Ala. '78
- *ALDRICH, TRUMAN H., JR., Min. Engr. and Coal Operator,
Aldrich Mining Co., 615 Brown-Marx Bldg., Birmingham, Ala. '96
- *ALDRIDGE, WALTER H.....14 Wall St., New York, N. Y. '89
- *ALEXANDER, CURTIS, Met.....Apartado 320, San Luis Potosi, Mexico. '84
- *ALLAN, JOHN F., Cons. Engr....62 London Wall, London, E. C., England. '90
- **ALLAN, THOMAS A., Care Fergus Allan, Mexico Mines of El Oro, Ltd.,
Apartado 17, El Oro, Mex., Mexico. '95
- *ALLDERDICE, TAYLOR, 3d Vice-Prest., National Tube Co.,
1711 Frick Bldg., Pittsburg, Pa. '92
- *ALLEN, ANSON W.....1616 So. 14th Ave., Birmingham, Ala. '87
- *ALLEN, JOHN A., Care G. Finnemore, 1191 Rivadavia,
San Juan, Argentine Republic, So. America. '07
- *ALLEN, JOHN H., Met.....Walpole, Mass. '84
- *ALLEN, JOSEPH W., Secy. and Treas., International Smelting & Refining Co.,
42 Broadway, New York, N. Y. '13
- *ALLEN, ROY H., Min. Engr.....64 No. 9th St., Newark, N. J. '09
- *ALLISON, ROBERT, Retired Mfr. Mining Machinery.....Port Carbon, Pa. '86
- *ALTHOUSE, HARRY W., Min. Engr.....Pottsville, Pa. '02
- *AMBROSIUS, CARL E., Mining.....La Prensa 79, Guanajuato, Mexico. '99
- *AMBROSIUS, JULIUS R., Mining.....Apartado 11, Guanajuato, Mexico. '99
- *AMMON, MARK A., Met. Engr., The Willys-Overland Co.....Toledo, Ohio. '12
- *AMMON, ROBERT, Chief Sampler, B. & M. Reduction Wks.,
Anaconda Copper Mining Co., Great Falls, Mont. '13
- *AMSDEN, FRANK F.....Jackson Iron & Steel Co., Jackson, Ohio. '87
- *AMSDEN, OTTO B., Min. Engr.....P. O. Box 431, Victor, Colo. '93
- **AMY, ERNEST J. H., Banker, H. Amy & Co., 44 Wall St., New York, N. Y. '85
- †ANDERSON, ALBERT H., Abrasive Mill Foreman, 22 Barber Ave.,
Worcester, Mass. '13
- *ANDERSON, ALBERT J., Min. Engr.....Socorro Mines, Mogollon, N. M. '03
- *ANDERSON, ALEXANDER, Min. Engr., Bella Vista, 22, Minas de Rio Tinto,
Prov. Huelva, Spain. '07
- *ANDERSON, ANDREW P., Min. Engr....908 Story Bldg., Los Angeles, Cal. '13
- *ANDERSON, AXEL E., Min. Engr., Tech. Div.,
E. I. Du Pont de Nemours Pdr. Co., 590 Du Pont Blk., Wilmington, Del. '04
- *ANDERSON, FRANK, Min. Engr., U. S. Deputy Mineral Surveyor,
Utah and Nevada, 468 South 12th East St., Salt Lake City, Utah. '96
- *ANDERSON, J. K., Civ. and Min. Engr..1414 Virginia St., Charleston, W. Va. '99
- *ANDERSON, MARTIN L., Mine Foreman, Liberty Bell Mine, Telluride, Colo. '02
- *ANDERSON, ROBERT HAY, Min. Engr....Apartado 866, Mexico City, Mexico. '95
- *ANDERSON, WILLIAM G.....519 N. Sacramento St., Stockton, Cal. '09
- **ANDREW, THOMAS, Min. Engr.....Rand Club, Johannesburg, So. Africa. '94
- *ANDREWS, CHARLES W., Treas., Zenith Furnace Co.....Duluth, Minn. '13

- *ANDROS, STEPHEN O., Min. Engr. University of Illinois, Urbana, Ill. '13
- *ANGERER, VICTOR, Vice-Prest. & Genl. Mgr., Wm. Wharton, Jr., & Co., Inc.,
25th St. & Washington Ave., Philadelphia, Pa. '13
- **ANTZ, EUGENE, Met. Homestead, Ore. '99
- *APGAR, FREDERICK W., Min. Geol. Canonbury Road, Jamaica, N. Y. '11
- *APLIN, WILLIAM, Met. Assayer, Instructor Chem.,
Moonta School of Mines, Moonta, So. Australia. '08
- *APPLEBY, WILLIAM R., Dean, Minnesota School of Mines; Prof. of Met.,
State University, Minneapolis, Minn. '90
- †APPLEGREN, JOHN O. W., Engr., Loope, via Markleeville, Alpine Co., Cal. '09
- *ARCHBALD, HUGH, Min. Engr. 236 Monroe Ave., Scranton, Pa. '11
- *ARCHBALD, JAMES, JR., Engr. and Agent, Girard Estate,
405 Thompson Bldg., Pottsville, Pa. '08
- **ARGALL, JOSEPH, Min. Engr. . . . Nantymwyn Mine, Llandoverly, S. Wales. '03
- *ARGALL, PHILIP, Min. Engr. and Met., 1st Nat. Bank Bldg., Denver, Colo. '92
- *ARKELL, HARRY J., Mining, 29 Clapham Mansions, Nightingale Lane,
London, S. W., England. '08
- *ARMAS, MILTIADES TH., Cons. Min. Engr.,
48 Blvd. Emile Augier 48 (16e), Paris, France. '96
- *ARMSIEAD, DANIEL MCP., Ingersoll-Rand Co., Farmers Bank Bldg., Pittsburg, Pa. '09
- **ARMSTEAD, HENRY H., Cons. Engr., Prest. Mexican United Co.,
29 Broadway, New York, N. Y. '00
- *ARMSTRONG, FRANK H., Mechanical Engineer. Vulcan, Mich. '14
- *ARMSTRONG, LYNDON K., Min. Engr. . . . P. O. Drawer 2154, Spokane, Wash. '07
- *ARMSTRONG, THOMAS, Chief Mineral Draftsman and Computer,
Care Surveyor General, Phoenix, Ariz. '95
- *ARNOLD, CHARLES E. LE N., Min. Engr., Inspiration Copper Co., Miami, Ariz. '06
- *ARNOLD, JOHN B., Attorney-at-Law, Room 840, 200 5th Ave., New York, N. Y. '14
- *ARNOLD, LEO F., Min. Engr. 719a Quincy St., Brooklyn, N. Y. '05
- *ARNOLD, RALPH, Cons. Geol. and Engr., Union Oil Co., Los Angeles, Cal. '12
- *ARTHUR, EDWARD P., JR. Bi-Metallic Bank, Cripple Creek, Colo. '97
- *ASANO, KOSAKU Vice-Mgr., Ashio Copper Mine, Shimotsuke, Japan. '14
- *ASHLEY, GEORGE H., Geol., U. S. Geological Survey, Washington, D. C. '99
- *ASHLEY, H. H. 164 South River St., Wilkes-Barre, Pa. '94
- *ASHMORE, ERNEST P., Cons. Min., Met. Engr.,
P. O. Box 531, So. Porcupine, Ont., Canada. '00
- **ASHMORE, G. PERCY, Cons. Min. Engr., 109 Lansdowne Pl., Hove,
Sussex, England. '97
- **ASHTON, FRANK, Min. Engr., Care N. J. Manson, City Hall, San Francisco, Cal. '00
- *ASTLEY, JOHN W., Cons. Min. Engr., 24 King St., W., Toronto, Ont., Can. '91
- *ATHA, BENJAMIN, Prest., Benj. Atha Co. (Crucible Steel Co. of America),
Newark, N. J. '84
- **ATHERTON, T. W. T., Chief Min. Engr., Ivory Coast Min. Corp.,
62 London Wall, London, E. C., England. '92
- *ATKIN, AUSTIN J. R., Min. Engr., Met.,
P. O. Box 6231, Johannesburg, Transvaal, South Africa. '06
- *ATKINSON, LOUIS W., Prest., Mgr., St. Clair Colliery Co. Eagle, W. Va. '94
- *ATWATER, CHRISTOPHER G., Care The United Coke & Gas Co.,
17 Battery Place, New York, N. Y. '03
- *ATWATER, RICHARD M., JR., Min. Engr., Ladenberg, Thalmann & Co.,
25 Broad St., New York, N. Y. '97
- *AUER, CHARLES I., Assayer, Chem., Estacion de Pedriceña, Dur., Mexico. '04
- *AUSTIN, ALBERT M., Messimer & Austin, 55 Liberty St., New York, N. Y. '05

- *AUSTIN, EDWIN A., Min. Engr., Yukon Gold Co.....Stockton, Cal. '08
 *AUSTIN, JOHN F., Met.....Apartado 101, Monterey, N. L., Mexico. '10
 **AUSTIN, KENNETH, Cons. Min., Met. and Mech. Engr., P. O. Box 4305,
 Johannesburg, Transvaal, South Africa. '97
 *AUSTIN, LEONARD S., Min. and Met. Engr., Dooly Block, Salt Lake City, Utah. '94
 *AUSTIN, W. LAWRENCE.....P. O. Box 1061, Riverside, Cal. '82
 **AVERY, JOHN, Met. Engr., Amalgamated Zinc (De Bavay's), Ltd.,
 Broken Hill, N. S. W., Australia. '03
 †AYRES, EMMA L. C.....Bound Brook, N. J. '03
 *AYRES, W. S., Min. and Mech. Engr.....Hazleton, Pa. '73
- *BABB, PERCY A., Min. Engr., Ave. Cinco de Mayo No. 32, Mexico City, Mexico. '06
 *BABBITT, THOMAS D., Min. Engr.....Nampa, Canyon Co., Idaho. '99
 *BACHE, FRANKLIN, Min. Engr., Prest., McAlester Coal Co.,
 Fort Smith, Ark., and 505 Land Title Bldg., Philadelphia, Pa. '91
 *BACHERT, AUGUSTUS E., Civ., Min. Engr.....Tyrone, Blair Co., Pa. '08
 *BACKUS, GEORGE S., Min. Engr.....617 Lister St., Leadville, Colo. '07
 *BACORN, FREDERICK W.....Butte, Mont. '03
 *BADLAM, STEPHEN, Asst. Supt., Merchant Mill Dept.,
 Pittsburgh Crucible Steel Co., Midland, Pa. '99
 *BAECHTOLD, CHARLES A., Engr.....96 Liberty St., New York, N. Y. '13
 *BAER, GEORGE F., Prest., Philadelphia & Reading Railway Co.,
 Reading Terminal, Philadelphia, Pa. '92
 *BAGG, RUFUS M., JR., Prof. Geol. and Mineral, Laurence Coll., Appleton, Wis. '07
 **BAGGALEY, RALPH, Mfr. and Miner,
 Prest., Puritan Coke Co., 1291 Shady Ave., E. E., Pittsburg, Pa. '00
 *BAGGE, NILS O.....Room 1511, 19 Cedar St., New York, N. Y. '02
 *BAHNEY, LUTHER W., Met,
 Hammond Laboratory, Yale University, New Haven, Conn. '08
 *BAILEY, A. C., Min. Engr.....P. O. Box 751, Cobalt, Ont., Canada. '11
 *BAILEY, CHARLES, Treas., Reliance Tube Co., Arrott Bldg., Pittsburg, Pa. '86
 *BAILEY, FRANK C., Mine Mgr.....2903 W. Suito Ave., Spokane, Wash. '14
 *BAILEY, J. TROWBRIDGE, Min. Engr.....32 W. 40th St., New York, N. Y. '02
 **BAILEY, JAMES B.....Pine Forge, Berks Co., Pa. '00
 *BAILEY, MELBOURNE, Min. Engr.....Barkerville, B. C., Canada. '05
 *BAILLIE, FRANK S., Vice-Prest. and Genl. Mgr.,
 Columbia Gold Mining Co., Columbia Mine, Sumpter, Ore. '03
 *BAIN, H. FOSTER, Editor, *Mining and Scientific Press*,
 420 Market St., San Francisco, Cal. '97
 **BAIN, HUGH A.....Riverside, Cal. '00
 *BAIRD, DUDLEY, Met.,
 Pacific Foundry Co., Harrison and 18th Sts., San Francisco, Cal. '02
 *BAIRD, GEORGE A., Mining.....1416 Westminster Bldg., Chicago, Ill. '06
 *BAIRD, HENRY J. B.....West Chester, Pa. '03
 *BAIRD, LOUIS, Min. Engr.....Ixtilan del Rio, Tepic, Mexico. '09
 *BAKER, CHARLES J. S., Civ. Engr., Met., 15 Eldon Rd.,
 Kensington, London, W., England. '08
 *BAKER, DAVID, Met. Engr., Ingall St., Mayfield, Newcastle, N. S. W., Australia. '86
 *BAKER, HUGH C., Engr., King. Cons. Co.,
 Union Bank Bldg., Ottawa, Ont., Canada '07
 *BALDWIN, WILLIAM S., Min. Engr.....170 South Broadway, Nyack, N. Y. '06
 *BALFOUR, J. FORDYCE, Min. Engr., Eversley, Portebello, Edinburgh, Scotland. '04
 *BALL, SYDNEY H.....71 Broadway, New York, N. Y. '07

- *BALTA, JOSE, Ingeniero de Minas..... Mogollon 13, Lima, Peru, So. America. '02
- *BANCROFT, GEORGE J., Min. Engr.....222 McPhee Bldg., Denver, Colo. '98
- *BANCROFT, HOWLAND, Min. Geol.....730 Symes Bldg., Denver, Colo. '09
- *BANKS, EDWIN G., Met.....P. O. Box 28, Waihi, Auckland, N. Z. '00
- *BANKS, HARRY P., Chem., 5715 Meridian St., Highland Park, Los Angeles, Cal. '08
- *BANKS, JOHN H., Min. Engr. and Chem., Ricketts & Banks,
80 Maiden Lane, New York, N. Y. '83
- *BANKS, NOBLE C., Min. and Met. Engr.,
Care Gear Grinding Mach. Co., Boulevard & Chene Sts., Detroit, Mich. '97
- **BANON, HENRY C., Min. Engr., P. O. Box 144, Chemainus,
Vancouver Isd., B. C., Canada. '90
- **BARBER, GEORGE MARRIOT, Min., Met. Engr., Supt., Frontino & Bolivia G.
M. Co., La Salada, care Empresa Hanseatica, Barranquilla, Colombia,
So. Am. '02
- *BARBER, JOHN C., Mine Supt.....Ketchikan, Alaska. '05
- *BARBER, RAYMOND J., Min. Engr.....88 Broad St., Boston, Mass. '13
- *BARBOUR, PERCY E., Min. Engr., Mgr., Uwarra Mining Co., Candor, N. C. '03
- **BARBOUR, THOMAS J., Min., Mech. Engr., Metropolitan Club, New York, N. Y. '97
- *BARD, DARSIE C., Min. Engr., Montana State School of Mines, Butte, Mont. '05
- *BARDWELL, ALONZO F., Min. Engr., Successor to Bettles, Mathez & Co.,
158 S. W. Temple St., Salt Lake City, Utah. '89
- *BARDWELL, EARL S., Genl. Concentrator Foreman,
Boston & Montana Reduction Wks., Great Falls, Mont. '13
- *BARKER, GEORGE, Mine Mgr.....Rosebery, Tasmania. '11
- *BARKER, HENRY A., Met. Engr., 315 Edificio Bancario,
Ave. Cinco de Mayo No. 32, Mexico City, Mexico. '02
- *BARKER, PIERCE, Met., Anaconda Copper Mining Co.,
P. O. Box 361, Anaconda, Mont. '13
- *BARKER, SAMUEL, JR., Civ., Min. Engr., Barker & Wilson....Butte, Mont. '00
- *BARLOW, ALFRED E., Min. Geol., 328 Roslyn Ave., Westmont, Que., Canada. '12
- *BARNARD, ENOCH A., Asst. in Testing Dept., Washoe Reduction Wks.,
Anaconda Copper Mining Co., 612 W. 5th St., Anaconda, Mont. '12
- *BARNES, BLAKESLEE, Min. Engr.....P. O. Box 493, Shreveport La. '13
- *BARNES, KENNETH F., Secty., Granby Min. & Smelt. Co., St. Louis, Mo. '13
- *BARNES, WALTER A., Min. Engr., Utah Metal Mining Co.,
Bingham Canyon, Utah. '13
- *BARNETT, MAURICE.....11 Pine St., New York, N. Y. '93
- **BARNETT, WILLIAM J., Cons. Min. Engr.,
3 London Wall Bldgs, London Wall, London, E. C., England. '02
- *BARNEY, MONTAGU T., Min. Engr., 155 Fenchurch St., London, E. C., England. '01
- *BARNHART, G. H., Min. Engr., Prest. and Genl. Mgr.,
The Mountain Top Mining Co., P. O. Box 1012, Ouray, Colo. '93
- *BARNUM, W. EUGENE, Supt. Blaisdell Coscotitlan Synd., Apartado 92,
Pachuca, Hid., Mexico. '12
- *BARRATT, SYDNEY A.....P. O. Box 148, Pleasantville, N. Y. '12
- *BARRELL, ROBERT W., Cons. Min. Engr. and Met., Asst. Mgr.,
St. Louis Sampling & Testing Works, 713 Clark St., St. Louis, Mo. '99
- *BARREN, HENRY A.....181 E. 93d St., Cleveland, Ohio. '02
- *BARRINGER, DANIEL M., Min. Engr., Geol., Bullitt Bldg., Philadelphia, Pa. '90
- *BARRON, GEORGE D.....P. O. Box 596, Rye, N. Y. '01
- *BARROWS, WALTER A., JR.Brainerd, Minn. '90
- *BARTLETT, ALBERT B., Min. Engr.220 W. 19th St., Cheyenne, Wyo. '07
- *BARTLETT, JAMES H.....Mng. Dir., American Assn., Inc., Middlesboro, Ky. '85

- *BARTLETT, JOHN R., Min. Engr., Red Metal Mining Co.,
553 Phoenix Bldg., Butte, Mont. '06
- †BARTLETT, WILLIAM S., Secy. to Public Companies, 80 Bishopsgate,
London, E. C., England. '07
- *BARTOL, GEORGE, Genl. Mgr., The Otis Steel Co., Ltd. Cleveland, Ohio. '79
- *BASSETT, WILLIAM H., Met. American Brass Co., Waterbury, Conn. '92
- *BASTIN, EDSON S., Geol. U. S. Geological Survey, Washington, D. C. '13
- *BATCHELLER, HENRY R., Cons. Min. Engr. Box 21, Washington, N. H. '95
- **BATCHELLER, JAMES H., Min. Engr. Mattapoisett, Mass. '00
- *BATCHELLOR, STILLMAN, Min. Engr., 1a San Augustin No. 12,
Mexico City, Mexico. '13
- *BATCHELOR, OWEN S., Mining. P. O. Box 221, Kamloops, B. C., Canada. '99
- *BATEMAN, ALAN M., Min. Geol., care of L. C. Graton, Geological Museum,
Cambridge, Mass. '14
- *BATESON, CHARLES E. W., Min. Engr., Chem., 43 E. 58th St., New York, N. Y. '01
- *BATZ, BARON RENE DE, Cons. Engr. 2 Ave. Camoëns, Paris, France. '95
- *BAUMANN, ALBERT P., Min. Engr. 939 Boulevard, East Weehauken, N. J. '99
- *BAUMGARTEN, K., Min. Engr. 616 Tinken Bldg., San Diego, Cal. '05
- *BAXTER, CHARLES H., Supt., Loretto Iron Co. Loretto, Mich. '12
- **BAYLISS, RAWLINSON T., Min. Engr., Chairman, Exploration Co., Ltd.,
11 Cornhill, London, E. C., England. '89
- *BEAL, LATHAM O. P. O. Box 370, Dunedin, New Zealand. '98
- *BEALE, ADDISON H. Vandergrift, Pa. '01
- **BEALE, HORACE A., Jr., Iron Mfr. Parkesburg, Pa. '06
- *BEALL, ALBERT, S. E., Hatfield Machinery Co., 306 E. 3d St., Los Angeles, Cal. '06
- *BEALL, CLARENCE A., Mine Mgr. P. O. Box 126, Hollywood, Cal. '06
- *BEARD, JOHN W., Mine Supt., Lane-Rincon Mines, Inc., Temascaltepec, Mex. '14
- *BEARD, JAMES T., Civ., Min. Engr., Senior Asso. Editor, *Coal Age*,
505 Pearl St., New York, N. Y. '06
- *BEATON, NORMAN H., Min. Engr., 305 Chamber of Commerce, Denver, Colo. '13
- *BEATTY, A. CHESTER, Cons. Engr. 71 Broadway, New York, N. Y. '96
- *BECK, EDWIN L., Assayer. Carrville, Cal. '04
- *BECK, ERICH ALFRED, Met., Goldschmidt Thermit Co.,
90 West St., New York, N. Y. '12
- Beck, Prof. Richard. Freiberg, Saxony, Germany.
- *BECKER, GEORGE F., Geol. U. S. Geological Survey, Washington, D. C. '93
- *BECKETT, JAMES A. Hoosick Falls, N. Y. '97
- *BECKETT, PERCY G., Min. Engr. Globe, Ariz. '13
- *BECKWITH, HENRY T., Field Geol., P. O. Box 95, Stanford University, Cal. '09
- *BEDDALL, THOMAS H., Min. Engr. Sprigg, Mingo Co., W. Va. '13
- *BEDFORD, ROBERT H., Min. Engr., North Star Mines Grass Valley, Cal. '12
- *BEEKEN, LEWIS L., Supt., Experimental Dept., Jones & Laughlin
Steel Co., Eliza Furnace, Pittsburg, Pa. '11
- *BEELER, HENRY C., Min. Engr. 127 Fifteenth St., Denver, Colo. '04
- *BEERS, ALBERT D., Ore Dept., New Jersey Zinc Co.,
55 Wall St., New York, N. Y. '13
- *BEHR, HANS C., Cons. Mech. Engr. 233 Broadway, New York, N. Y. '00
- *BEL, J. MARC, Expert pres le Conseil de Prefecture de la Seine,
90 Rue d'Amsterdam, Paris, France. '84
- *BELDEN, SANFORD B., Mgr. Min. Dept., The Jeffrey Manufacturing Co.,
Columbus, Ohio. '01
- *BELIN, HENRY, JR., Powder Mfr., Traders Nat. Bank Bldg., Scranton, Pa. '87
- *BELL, ALAN D., Min. Engr., St. Joseph Lead Co. Bonne Terre, Mo. '95

*BELL, CHARLES N., Min. Engr., First National Bank Bldg., Telluride, Colo.	'09
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- *COLLINS, FRANCIS W., Civ., Min. Engr.....50 Church St., New York, N. Y. '03
- **COLLINS, GEORGE E., Min. Engr.....420 Boston Bldg., Denver, Colo. '00
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- **COLLINS, HENRY F., Min., Met. Engr., Huelva Copper & Sulphur Mines,
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- *COLLINS, JOHN P., Blast Furnace Supt.....222 Mathilda St., Pittsburg, Pa. '05
- *COLLINS, W. J.....Instructed to hold all mail. '93
- *COLLORD, GEORGE L., Genl. Furnace Mgr.,
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- **COLQUHOUN, JAMES.....31 Ferndale, Tunbridge Wells, England. '98
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- *COLWELL, ALFRED B., Min. Engr.....P. O. Box 135, Ely, Nev. '03
- *COLYAR, LOUIS S., Prest., Eagle Iron Co.....Chattanooga, Tenn. '85
- *COMINGS, GEORGE R., Min. Engr.....Apartado 126, Oaxaca, Oax., Mexico. '05
- *COMINS, WALDO H., Supt., St. Louis Smelting & Refining Co.,
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- *COMSTOCK, CHARLES W., Civ., Min. Engr.,
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- *COMSTOCK, THEODORE B., Prest., *California Farm and Home Builder*,
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- *CONANT, H. D., Supt., Lake Superior Smelting Co.....Dollar Bay, Mich. '88
- *CONGDON, EDWARD C., Mining.....807 Lonsdale Bldg., Duluth, Minn. '14
- *CONLEY, OWEN J., Min. Engr.....Benson Mines, N.Y., '02
- *CONNER, ELI T., Min. Engr., Room 1315, Stephen Girard Bldg.,
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- **CONNOR, S. B., Gold Dredging and Mining, Mills Bldg., San Francisco, Cal. '88
- *CONRADSON, PONTUS H., Chief Chem., Galena Signal Oil Wks., Franklin, Pa. '92
- *COOK, EDGAR S.....Prest., Warwick Iron and Steel Co., Pottstown, Pa. '77
- *COOK, EDWARD B., Furnace Mgr.....743 King St., Pottstown, Pa. '06
- *COOK, EDWARD H., Min. Engr., Mgr. & Owner, Minas de Birimoa,
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- *COOK, FREDERICK S., Cons. Min. Engr.....Joplin, Mo. '07

- *COOK, JAMES B., Supt., Berwind-White Coal Mining Co., Spirit Bldg.,
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- *COOK, ROBERT A., Portland Cement.....229 Broadway, New York, N. Y. '83
- *COOKE, FREDERICK W., Secy. & Treas., Hardinge Conical Mill Co.,
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- *COOKE, HENRY M. A., Min. Engr., Supt., Balaghat Gold Mining Co., Ltd.,
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- **COOKE, LEWIS H.....Royal School of Mines, London, S. W., England. '01
- **COOLIDGE, WALTER G., Copper Ref., Chicago Copper Refining Co.,
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- **COOPER, HUGH L., Cons. Engr.....101 Park Ave., New York, N. Y. '06
- ††COOPER, JAMES B., Supt., Calumet and Hecla Smelter.....Hubbell, Mich. '99
- **COOPER, JOHN.....52 Pinhoe Rd., Exeter, Devonshire, England. '03
- *COOPER, JOHN H., Min. Engr.....428 W. 49th St., Los Angeles, Cal. '13
- *COOPER, MAURICE D., Min. Engr.,
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- *COOTE, CHARLES E., Min. Engr., Mt. Lyell Comstock Copper Co.,
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- *COPELAND, DURWARD, Met., Cia. Estamifera de Llallagua, Llallagua,
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- *COPELAND, F. K., Prest., Sullivan Machy. Co.,
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- *CORBIN, J. ROSS, Cons. Engr.....1729 Master St., Philadelphia, Pa. '11
- **CORBOULD, WILLIAM HENRY, Genl. Mgr., Mount Elliott Mine,
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- *CORBUS, A. W.....1416 Willow St., Alameda, Cal. '00
- **CORBUS, J. PARKER.....P. O. Box 123, Los Gatos, Cal. '96
- *COREY, W. E.....14 Wall St., New York, N. Y. '94
- *CORFIELD, REGINALD W. G., Met., 5 Richmond Villas, Swansea, England. '06
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- *CORKILL, FREDERICK, Min. Engr.....2611 Ashby Ave., Berkeley, Cal. '07
- *CORLESS, C. V., Min. Engr.....Coniston, Ont., Canada. '08
- *CORNELIUS, WILLIAM A., Mgr., Natl. Dept.,
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- *CORNELL, ROY L. G.....1288 W. 23d St., Los Angeles, Cal. '12
- **CORNELL, RUSSELL T., Min. Engr.....45 Cedar St., New York, N. Y. '02
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- *CORNING, FREDERICK G., Min. Engr.....35 Wall St., New York, N. Y. '77
- *CORNISH, HARRY L., Min. Engr.....54 Natoma St., San Francisco, Cal. '03
- †CORRY, ARTHUR V., Min. Engr.....203 Lewishon Bldg., Butte, Mont. '97
- *CORSA, DEAN, Min. Engr., Vice-Prest. and Genl. Mgr., Wytheville Iron Co.,
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- *CORWIN, FRANK R., Smelter Foreman,.....P. O. Box 1265, Clifton, Ariz. '13
- *COSBY, FREDERICK N., Min. Engr.,
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- *GOSGRO, JOHN P.....Apartado Postal 447, Mexico City, Mexico. '01
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- **COUMERILH, WILLIAM, Mine Operator.....Mullan, Idaho. '95
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- *COWANS, FREDERICK, Min. Engr., Utah Consolidated Mining Co.,
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- **COWLES, ALFRED H.....Sewaren, N. J. '86
- *COX, GUY H., Teaching and Mining.....Rolla, Mo. '12
- *COX, HERBERT B., Ringwood Co.....50 Church St., New York, N. Y. '04
- *COX, THOMAS, Cons. Engr.....463 Ellita Ave., Oakland, Cal. '01
- *COX, WILLIAM J.....304 Boston Bldg., Denver, Colo. '93
- *COX, W. RAY, Min. Engr., Assayer, Chem., Field Div.,
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- *COX, W. ROWLAND, Mine Mgr.....165 Broadway, New York, N. Y. '03
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- **COXE, ECKLEY B., JR., Anthracite Coal Operator.....Drifton, Pa. '93
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- *CRANE, GERARD A., Min. Engr....6 Gt. Winchester St., London, England. '04
- †CRANE, THERON I., Pilling & Crane, Real Estate Trust Bldg., Philadelphia, Pa. '92
- *CRANE, WALTER R., Prof. Mining, Pa. State College.....State College, Pa. '00
- *CRANKSHAW, HUGH M., Min. Engr., Lehigh Coal & Navigation Co., Lansford, Pa. '12
- *CRANSTON, ROBERT E., Mine Mgr....437 Holbrook Bldg., San Francisco, Cal. '99
- *CRARY, CHARLES N., Mining.....Valdez, Alaska. '08
- *CRAWFORD, GEORGE G., Prest., Tennessee Coal, Iron & R. R. Co.,
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- *CRAWFORD, HENRY E., Min. Engr., Care J. G. Crawford, 450 81st St.,
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- *CRAWFORD, JOHN, JR., Mgr., Noble Elec. Steel Co.....Herault, Cal. '13
- *CRAWFORD, JOHN J.....Bohemia Club, San Francisco, Cal. '73
- *CRAWFORD, RUFUS C., Coal Operator.....McKeesport, Pa. '10
- **CRAWFORD, WALTER H., Cons. Min. Engr....39 Rutland Sq., Boston, Mass. '05
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- *CREMER, DR. FRITZ, Met. Engr., Marshall-Wells Hdw. Co., Duluth, Minn. '07
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- **CRESPI, R. A., Mining, Care John M. Keith, San José, Costa Rica, C. A. '05
- *CREWE, LEONARD C., Genl. Mgr., La Follette Iron Co..La Follette, Tenn. '03
- *CRICHTON, ANDREW B., Min. Engr.....Johnstown, Pa. '10
- ||CRITTENDEN, ZAR T., Min. Engr.....Lincoln Blk., Butte, Mont. '13
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- †CROWTHER, JOHN S., JR., Asst. Supt., Toledo Furnace Co., Toledo, Ohio. '12
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- *CRUM, J. RICHMOND, Min. Engr. Trentham, Stoke-on-Trent, England. '07
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- *CULLUM, J. BARLOW. Pottsville, Pa. '91
- *CUMINGS, W. L., Geol. and Min. Engr. 409 E. Broad St., Bethlehem, Pa. '06
- *CUMMINGS, WILLIAM N., Min. Engr. R. F. D. 3, Box 62, Orange, Cal. '93
- *CUMMINS, HARLE O. Redding, Cal. '07
- *CUMMINS, WILLIAM N., Min. Engr., Genl. Supt., Red Jacket Cos. Coal &
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- *CUNNINGHAM, ECKLEY S., Mgr., Mines, Water Co.; Engr.,
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- *CUNNINGHAM, JAMES S. National City Bank Bldg., Charleston, W. Va. '83
- *CUNNINGHAM, JOHN C., Engr., Care Broken Hill South Silver Mining Co.,
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- *CUNNINGHAM, NOEL, Met. Engr., Hollinger Gold Mines, Ltd.,
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- *CUNNINGHAM, PARKER H., Min. Engr., 306 N. Jefferson St., New Castle, Pa. '05
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- *DAKIN, FREDERICK H., JR., Min. Engr., 110 Sutter St., San Francisco, Cal. '04
- *DALBURG, FRANK A. Arctic Coal Co., Tromsø, Norway. '04
- *DALE, WILLIAM C., Min. Engr., Casilla 230, Copiapo, Chile, So. America. '12
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- *DANIEL, WILLIAM B., Min. Engr. 14 Mesa Ave., Piedmont, Cal. '00
- *DANIELL, JOHN. 89 Third St., Laurium, Mich. '10
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- *DARLINGTON, WAYNE, Cons. Min. Engr. and Met. Georgetown, S. C. '95
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- *DARTON, N. H., Geol., U.S. Geol. Survey. Washington, D. C. '94
- *DAVELER, ERLE V. Alaska Gastineau Co., Juneau, Alaska. '09
- *DAVIDSON, GEORGE M., Chem. and Engr. of Tests,
Chicago & Northwestern Ry. Co., Chicago, Ill. '81
- *DAVIDSON, OTTO C., Genl. Supt., Iron Mines, Oliver Iron Mining Co.,
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- *DAVIES, JOHN E., Engr., Morro Velho, Villa Nova de Lima Mines,
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- *DAVIES, WILLIAM H., Div. Supt., Lehigh Valley Coal Co. Hazleton, Pa. '97
- *DAVIS, ANGUS W., Mining Engineer,
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- *DAVIS, BRITTON, Mine Mgr.,
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- *DAVIS, CARL R., Min. Engr., Genl. Mgr., Lancaster Gold Mining Co., Ltd.,
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- *DAVIS, WALTER W., Attorney at Law. Leadville, Colo. '12
- *DAVIS, WILLIAM J., JR., Pacific Coast. Engr., General Electric Co.,
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- *DAWBARN, GILBERT J., Min. Engr..... Wallaroo Mines, South Australia. '04
- *DAY, ARTHUR M..... International S. & R. Co., Tooele, Utah. '03
- **DAY, DAVID T., Petroleum Expert, U. S. Geological Survey,
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- *DAY, WILLIAM H., JR., Mfg. and Mining..... Dubuque, Iowa. '00
- **DEAN, A. L., Met..... Quebec Bank, Quebec, Canada. '96
- *DEARDORFF, ALPHEUS E., Mine Foreman,
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- *DE DEKEN, ALBERT, Met., Min. Engr. and Chem.,
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- *DEEGEN, JOHN, Mine Engr..... Hemet, Cal. '09
- *DEFTY, WILLIAM E., Min. Engr..... Phoenix, Ariz. '02
- *DE HORA, MANUEL H., Cons. Min. and Civ. Engr.,
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- *DEIDESHEIMER, PHILLIPP, Min. Engr., 2808 Clay St., San Francisco, Cal. '00
- *DEIKE, GEORGE H..... Bureau of Mines, Pittsburgh, Pa. '06
- *DEKALB, COURTENAY, Cons. Engr., Pacific Smelting & Mining Co.,
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- **DELANO, WARREN, Coal Operator..... 1 Broadway, New York, N. Y. '92
- *DE LASHMUTT, IVAN, Min. Engr., Supt., Standard Silver-Lead Mining Co.,
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- *DEL MAR, ALGERNON, Min. Engr..... South Pasadena, Cal. '93
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- *DENNEUFVILLE, DR. RUDOLPH, Bockenheimeranlage 45, Frankfort a/M.,
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- *DEVEREUX, W. B., Cons. Min. Engr.....60 Broadway, New York, N. Y. '80
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- *JONES, EVAN R., Supt.....Eagle Pass, Tex. '02
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- *JONES, LLEWELLYN W., 616 E. Montgomery Ave.....Bryn Mawr, Pa. '13
- *JONES, THOMAS D.....Vice-Prest., Mill Creek Coal Co., Hazleton, Pa. '75
- *JONES, THOMAS J., Mine Mgr., Kyshtim Mining Wks., Perm Govt.,
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- *JONES, ZECHARIAH, Constr. Engr. . . . Idaho Continental Mines, Port Hill, Ida. '12
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- *JORDAN, HAROLD S., Min. Engr. Campo Seco, Cal. '12
- *JUDSON, WILBER, Min. Engr. Gage, New Mexico '14
- *JORGENSEN, FRANK F., Min Engr. Gillespie, Ill. '12
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- **KAYSER, HENRICH W. F. "Willerden," E. St. Kilda, Melbourne, Vic., Australia. '95
- *KEADY, LYNN Y., Mining . . . 1016 Board of Trade Bldg., Portland, Ore. '10
- *KEATING, JOHN B., Min. Engr. and Met., Genl. Supt., Bully Hill Mines,
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- *KEHLER, CHARLES R., Company Director.....Instructed to hold all mail. '02
- *KEHOE, HENRY, Min. Engr.....South 1123 Wall St., Spokane, Wash. '00
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- **KELLY, WILLIAM, Genl. Mgr., Penn Iron Mining Co.....Vulcan, Mich. '90
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- *KERR, MARK B., Cons. Engr.....Mills Bldg., San Francisco, Cal. '90
- *KERVIN, GEORGE A., Asst. Supt.....Mammoth Smelter, Kennett, Cal. '12
- *KERVIN, J. H.....Care Mammoth Copper Mining Co., Kennett, Cal. '95
- *KEYES, CHARLES R.....944 5th St., Des Moines, Iowa. '99
- *KIBE, KAZUYE, Min. Engr., Furokura Mine, Oyu-Mura, Akita-Ken, Japan. '10
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- *KING, FREDERICK G., Prest. & Genl. Mgr., Boston-Pacific Oil Co.,
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- *KLEINSCHMIDT, CHARLES, Mining, Calle Orizaba, No. 42 (Colonia Roma),
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- *KLEINSCHMIDT, FRANZ H., Min. Engr., Blue Jacket Copper Co., Landore, Idaho. '13
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- *KOCH, GEORGE B., General Foreman, P. R. R. Foundries. Altoona, Pa.
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- *LACHMUND, OSCAR, Min. Engr.....Greenwood, B. C., Canada. '14
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- *LANDRUM, CHARLES W., Cons. Engr.....602 Keystone Bldg., Joplin, Mo. '03
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- *LASSITER, ROBERT G., Mine Mgr. Virgilina, Va. '09
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- *MACKAY, HENRY S., Min. Engr., Mackay Copper Process Co., Norwich, Conn. '06
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- *MALCOLMSON, JAMES W., Cons. Engr., Lucky Tiger Combination G. M. Co.,
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- *MARKLE, JOHN, Min. Engr.....G. B. Markle & Co., Jeddo, Pa. '79
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- **MARRINER, JOHN T., Pahang Consolidated, Kuantan Pahang, Singapore. '01
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- *MARSHALL, STUART B., Asst. Genl. Mgr., Dunbar Furnace Co., Dunbar, Pa. '10
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- *MARTIN, NICHOLAS J., Supt. Beaver Gold Dredging Co., Loomis, Cal. '00
- *MARTIN, ROBERT L., JR., Mingo Washed Coal Co.,
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- *MASIAS, MANUEL G., Cons. Engr., Sociedad de Ingenieros, Lima,
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- *MATHER, THOMAS W. Casilla 655, Guayaquil, Ecuador, So. America. '08
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- *MAURICE, JUAN, Min. Engr., Mgr., The Royal Silver Mines of Potosi,
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- *MAYNARD, EDWARD W., Chem. Atlas Powder Co., Senter, Mich. '12
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505 Pearl St., New York, N. Y. '01
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- **MOLLER, WARDEN A., Min. Engr.,
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Ducktown Sulphur, Copper & Iron Co., Isabella, Tenn. '02
- *REQUA, MARK L., Min. Engr., 1023-26 Crocker Bldg., San Francisco, Cal. '00
- *REVELL, GEORGE E.....P. O. Box 132, Nelson, B. C., Canada. '00
- *REVERE, JOSEPH W., Min. Engr., Purchasing Agent, Dominion Coal Co., Ltd.,
Glace Bay, Cape Breton, N. S., Canada. '81
- *REVETT, BENJAMIN S., Prest. and Genl. Mgr.,
Reliance Gold Dredging Co., Breckenridge, Colo. '96
- *REYNDERS, JOHN V. W., Vice-Prest., Penna. Steel Co.....Steelton, Pa. '12
- **REYNOLDS, GEORGE B., Min., Met. Engr.,
15 Victoria St., Westminster, London, S. W., England. '91
- *REYNOLDS, HENRY D. G., Min. Engr., Penn-Ariz. Min. Co., Walker, Ariz. '06
- **REYNOLDS, LLEWELLYN.....Address wanted. '02
- *REYNOSO, JOSE J., Min. Engr.....Apartado 768, Mexico City, Mexico. '08
- *RHEW, JAMES W., Supt., Penafiel Mine, Guanajuato Cons. M. & M. Co.,
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Ltd., Shortland St., Auckland, New Zealand. '98
- *RHODES, CLARENCE E., Care El Oro Min. & Ry Co., Apartado 30,
El Oro, Mex., Mexico. '05
- *RHODES, FRANCIS B. F.....Bergerville, Prov. Quebec, Canada. '76
- **RHODES, FRED N., Mgr.....White Island Sulphur Co., Opatiki, New Zealand. '07
- *RHODES, WILLIAM B., Civ., Min. Engr., Care E. E. Rhodes,
Mendocina City, Cal. '03
- *RIBALKIN, MICHAEL P., Prof. of Met., Vassilevsky Ostrov. No. 17 on 11,
St. Petersburg, Russia. '13
- *RICE, EUGENE R., Min. Engr.....Box 2266, Bisbee, Ariz. '08
- *RICE, GEORGE S., Cons. Engr.....154 Nassau St., New York, N. Y. '86
- *RICE, GEORGE SAMUEL, Chief Min. Engr., U. S. Bureau of Mines,
40th and Butler Sts., Pittsburg, Pa. '96
- *RICE, JOHN, General Crushed Stone Co., Inc.....Drake Bldg., Easton, Pa. '92
- *RICE, JOHN A., Min. Engr. and Geol., Drawer 994, Haileybury, Ont., Canada. '00
- †RICE, WILLIAM E., Master Mechanic, Ringwood Mines, Ringwood Manor, N. J. '13
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- *RICHARDS, F. B.**, Chem., Mgr., Iron Ore & Pig Iron Dept., M. A. Hanna & Co.,
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- *RICHARDS, GEORGE M.**, Chief Min. Engr., Compagnie des Chemin de Fer du
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- *RICHMOND, WILLIAM H.**..... Richmond Hill, Scranton, Pa. '87
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- *RICKARD, FORBES**, Min. Engr..... 508 Equitable Bldg., Denver, Colo. '92
- *RICKARD, HAROLD**, Min. Engr., Southern Shan States Synd. (1909), Ltd.,
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- *RICKARD, RICHARD D.**, Secy. and Teas., New York, Ontario & Western Ry. Co.,
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- *RIDDELL, GUY C.**, Supt., American Smelting & Refining Co., East Helena, Mont. '13
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- *RIEDT, CARLOS**..... Kant-Str. 38*, Charlottenberg, Germany. '99
- **RIES, HEINRICH**..... Prof. Econ. Geol., Cornell University, Ithaca, N. Y. '95
- *RIGG, GILBERT**, Met..... Palmerton, Pa. '13
- *RIGGS, GEORGE W.**, Care L. Riggs, Jr.... 27 William St., New York, N. Y. '74
- *RIGHTER, THOMAS M.**, Vice-Prest., Midvalley Coal Co., Mount Carmel, Pa. '99
- *RIGHTMIRE, ROBERT E.**, Fuel Engr., Consolidation Coal Co., Fairmont, W. Va. '12
- *RILEY, LEWIS A.**, Min. Engr., Prest., Lehigh Coal and Navigation Co.,
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- *RING, AMBROSE E.**, Mining Dept., Federal Lead Co..... Flat River, Mo. '05

- *RIO, JOSE P., Chief Engr., Irrigation & Water Supply of Brazil,
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- *RIORDAN, DENIS M. Room 2025*, 165 Broadway, New York, N. Y. '82
- *RISQUE, JAMES B., Mgr., Tennessee Copper Co. Copperhill, Tenn. '13
- *RISSMANN, OTTO. Genl. Mgr., National Zinc Co., Bartlesville, Okla. '89
- *RITER, GEORGE W., Secy., Eureka Hill Mining Co., Salt Lake City, Utah. '99
- *RITER, LEVI E., JR., Min. Engr., 306 Newhouse Bldg., Salt Lake City, Utah. '08
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- *RODDEWIG, GEORGE W., Engr. Cœur d'Alène Ironworks, Ltd., Wallace, Idaho. '12

- *RODEN, BENJAMIN F., Prest., Roden Coal Co.....Marvel, Ala. '12
- *RODGERS, C. EARL, Min. Engr., Assayer, Dome Mines Co.,
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- *RODGERS, SELDEN S., Foreman., McDougall Furnace Dept.,
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- *RODRIGUEZ, JUAN C., Min., Met. Engr., Apartado 87, Saltillo, Coah., Mex. '99
- *ROE, JAMES P., Mech. Engr., Genl. Supt., Iron Mills, Glasgow Iron Co.,
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- *ROE, JOSEPH W., Asst. Prof. Mech. Engrg., Sheffield Scientific School,
Yale Univ., New Haven, Conn. '10
- *ROEBER, E. F., Editor, *Metallurgical and Chemical Engineering*,
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- *ROEBLING, CHARLES G., Mfr. of Wire Rope.....Trenton, N. J. '06
- *ROEBLING, FERDINAND W., Jr., Engr.,
Care John A. Roebling's Sons Co., Trenton, N. J. '06
- †ROESER, ERNEST B., Min. Engr.....Kanawha Falls, W. Va. '12
- *ROESER, FREDERICK, Supt., Globe Plant, American Smelting & Refining Co.,
Denver, Colo. '94
- *ROESLER, MAX B.,.....Great Neck, L. I., N. Y. '07
- *ROGERS, ALEXANDER P., Min. Engr...60 Broadway, New York, N. Y. '04
- *ROGERS, ALLEN H.,.....201 Devonshire St., Boston, Mass. '92
- *ROGERS, CHARLES E., Fraser & Chalmers, Ltd.,
3 London Wall Bldgs., London, E. C., England. '97
- *ROGERS, E. M., Cons. Min. Engr.....32 Broadway, New York, N. Y. '82
- *ROGERS, WILLIAM B., Min. Engr.....60 Broadway, New York, N. Y. '12
- **ROHLFFS, WALTER U., Min. Engr...1120 Lombard St., San Francisco, Cal. '13
- *ROHN, OSCAR, Min. Engr....East Butte Copper Mining Co., Butte, Mont. '05
- *ROLKER, CHARLES M.,.....1 Leadenhall St., London, E. C., England. '74
- *ROLLE, SIDNEY, Min. Engr., U. S. Metals Refining Co....Chrome, N. J. '13
- *RONE, LLOYD A., Min. Engr.....Apartado 333, Torreon, Coah., Mex. '05
- *ROOD, VERNON S., Mine Supt., Utah Apex Mining Co., Bingham Canyon, Utah. '12
- *ROOT, JOHN A., Chem.,.....P. O. Box 443, Anaconda, Mont. '13
- *ROPP, ALFRED VON DER, Met.....233 Broadway, New York, N. Y. '01
- *ROSE, GEORGE E., Blast Furnace Supt....6758 Bennett Ave., Chicago, Ill. '07
- *ROSE, HUGH, Min. Engr...Cia. de Santa Gertrudis, Pachuca, Hid., Mexico. '00
- *ROSE, WILLIAM W., Mine Broker.....1428 Montana St., El Paso, Texas. '82
- *ROSENFELD, LOUIS, Mining.....Merchants Exchange, San Francisco, Cal. '99
- *ROSEWARNE, DAVID D., Mine Engr., Royal Colonial Inst.,
Northumberland Ave., London, W. C., England. '90
- *ROSS, ALEXANDER J. M., Asst. Min Engr., Homestake Mining Co., Lead, S. D. '07
- *ROSS, EDWARD P., Chem. & Furn. Mgr., Supt., Colonial Iron Co.,
Riddlesburg, Pa. '13
- *ROSS, FRANK A., Cons. Engr.....Spokane Club, Spokane, Wash. '85
- *ROSS, GILBERT McM., Mine Mgr.....Yosemite Club, Stockton, Cal. '05
- *ROSS, HERBERT W., Genl. Smelter Supt., Backus & Johnston Co.,
Casapalca, Peru, So. America. '08
- *ROSS, JAMES G., Cons. Min. Engr., Milton Hersey Co., 171 St. James St.,
Montreal, Canada. '07
- *ROSS, LEWIS P., Mgr.....Northern Iron Co., Standish, N. Y. '06
- *ROSS, LOUIS, Cons. Engr.,79 Milk St. Boston, Mass. '13

- *ROSSI, AUGUSTE J., Electro-Metallurgy... 35 Broadway, New York, N. Y. '92
- *ROTHSCHILD, CLARENCE G., Min. Engr. and Operator,
43 Leonard St., New York, N. Y. '05
- *ROWAND, LEWIS G., Elect. Engr. and Met... Manhattan Ave., Seagate, N. Y. '02
- *ROWE, FREMONT S., Supt., Hecla Mine..... Burke, Idaho. '12
- *ROYCE, STEPHEN, Mine Surveyor.. Pickands, Mather & Co., Hurley, Wis. '09
- *RUBEL, MILTON L., Min. Engr., Mgr., Pilonas Min. Co., Topia, Dur., Mexico. '06
- *RUBIDGE, FREDERICK T., Min Engr.,..... 41 Broad St., New York, N. Y. '13
- *REUTSCHI, RUDOLF, Cons. Engr..... P. O. Box 626, Hammond, Ind. '91
- *RUGGLES, GUY H., Min. Engr..... Clifton, Ariz. '09
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- *RULE, J. ARTHUR..... Int. Smelt. & Refg. Co., Tooele, Utah. '06
- *RUMBOLD, WILLIAM R., Min. Engr., Union Club... Trafalgar Sq., London, Eng. '06
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- *RUSSELL, EDWARD H..... P. O. Box 496, New Haven, Conn. '84
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Woodstock, Grove Crescent Rd., Kingston-on-Thames, England. '02
- *RUSTERHOLZ, RUDOLPH W., Butte Branch, Ingersoll-Rand Co.,
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- *RUTHERFORD, FOREST, Asst. Supt. of Reduction Works,
Care Copper Queen Reduction Works, Douglas, Ariz. '00
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- *RYDER, THOMAS J..... Apartado 1203, Mexico City, Mexico. '01
- *RYS, C. F. W., Met. Engr., Carnegie Steel Co., Carnegie Bldg., Pittsburg, Pa. '13
- *SACKETT, CHARLES T., Civ. and Min. Engr..... Livingston, Mont. '11
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- *SALE, ANDREW J., Min. Engr., Giroux Cons. Mines Co.... Kimberly, Nev. '13
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- *SALISBURY, EARL F..... Villaldama, Nuevo Leon, Mexico. '06
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- *SANDERS, JOHN D., Asst. Mgr. Solvay Process Co., Detroit, Mich. '79
- *SANDERS, R. H., Min. Engr. 617 Drexel Bldg., Philadelphia, Pa. '76
- *SANDERS, WILBUR E., Cons. Min. Engr. Alkali Mines Co., Eureka, Nev. '85
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- *SARGENT, FITZ-WILLIAM, Chief Engr., Am. Brake Shoe & Fdy. Co., Mahwah, N. J. '12
- *SARGENT, WILLIAM D. Hutton Park, West Orange, N. J. '96
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- *SAUNDERS, WILLIAM E. Torrissdale, Pa. '89
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- *SAXMAN, EDWIN F. Villanova, Pa. '06
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- **SCAIFE, WILLIAM B. Structural Iron Works, Oakmont, Pa. '01
- **SCAIFE, WILLIAM L., Scaife Foundry and Machine Co. Pittsburg, Pa. '79
- †SCALLON, WILLIAM. Helena, Mont. '90
- *SCARBOROUGH, FRANCIS W., Cons. Engr., Travelers Bldg., Richmond, Va. '02
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301 Columbia Trust Bldg., Los Angeles, Cal. '07
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Merchants Exchange Bldg., San Francisco, Cal. '96
- *WILES, EDWIN L. Stony Point, Rockland Co., N. Y. '82
- **WILEY, WALTER H., Min. Engr., 367 S. Bonnie Brae St., Los Angeles, Cal. '96
- *WILEY, WILLIAM H., Scientific Publisher, 432 Fourth Ave., New York, N. Y. '81
- *WILEY, W. MURDOCH 32 W. 40th St., New York, N. Y. '00
- *WILFLEY, CLIFFORD R., Min. Engr. P. O. Box 1721, Denver, Colo. '12
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London, E. C., England. '12
- *WILKINS, WILLIAM, Mgr., Lake Superior Iron & Chem. Co., Ashland, Wis. '91
- *WILKINS, WILLIAM GLYDE, Civ. and Min. Engr., Wm. G. Wilkins Co.,
Westinghouse Bldg., Pittsburg, Pa. '91
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Apartado 7, Real del Monte, Hid., Mexico. '09
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Goldfield, Nev. '97
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P. O. Box 485, Johannesburg, Transvaal, So. Africa. '03
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Whitchurch, Hants, England. '88
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Kimberley, So. Africa. '97
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- *WILLIAMS, DANIEL J., Min. Engr., Mgr. Continental Development Co.,
Skeena Crossing, B. C., Canada. '14
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- *WILLIAMS, EDWARD G., Vice-Prest., J. G. White Engrg. Corpn.,
43 Exchange Pl., New York, N. Y. '97
- *WILLIAMS, EDWARD H., JR. "Westerdale," Woodstock, Vt. '76
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Rio Janeiro, Brazil, So. Am. '14
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 Golden, Colo. '03
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 *WOLF, OTTO C., Engr., Architect,
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 *WOLFF, MARK A., Assayer and Chem.,
 618 Pacific Bldg., Vancouver, B. C., Canada. '06
 *WOLFLIN, HUGH M., Engr., Industrial Accident Commission,
 409 Underwood Bldg., San Francisco, Cal. '10
 *WOLLE, HARTLEY C., Genl. Supt., Cambria Steel Co.....Johnstown, Pa. '86
 *WOMBLE, LLOYD A., Genl. Mgr., Geduld Proprietary Mines, Ltd.,
 Box 41, Springs, Transvaal, So. Africa. '03
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 New York, N. Y. '13
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 near Tientsin, North China. '00
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 43 Exchange Place, New York, N. Y. '76
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 P. O. Box 1503, Great Falls, Mont. '80
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 New York, N. Y. '05
 *WOODS, FRANCISCO J., Supt. of Mines and Mills,
 Apartado 161, Oaxaca, Oaxaca, Mexico. '06
 *WOODS, FRANK M., Western Financing Corp.,
 63-64 Independence Bldg., Colorado Springs, Colo. '98

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 *WORTH, JOHN G., Min. Engr. P. O. Box 11, El Rito, N. M. '09
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 So. Kensington, London, England. '12
 *WRAITH, WILLIAM, Met., International S & R Co.,
 Kearns Bldg., Salt Lake City, Utah. '03
 *WRIGHT, CHARLES O., Min. Engr., Asst. Engr.,
 Fayette Engineering Co., Uniontown, Pa. '10
 *WRIGHT, CHARLES W. Ingurtozu, Arbus, Sardinia, Italy. '05
 *WRIGHT, CLARENCE A., Min., Met. Engr., U. S. Bureau of Mines,
 Washington, D. C. '12
 *WRIGHT, EDWARD T., Ore Milling Engr.,
 1730 1st Natl. Bank Bldg., Chicago, Ill. '09
 *WRIGHT, FREDERIC E. Geophysical Laboratory, Washington, D. C. '04
 *WRIGHT, GEORGE A., Engr., Spanish-American Iron Co., Felton, Oriente, Cuba. '13
 *WRIGHT, HERBERT B., Engr., Pocahontas Cons. Collieries Co., Pocahontas, Va. '05
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 †WRIGHT, WILFRED L., Vice-Prest., Tioga Steel & Iron Co., Land Title Bldg.,
 Philadelphia, Pa. '13
 *WRIGHT, WILLIAM Q., Min., Civ. Engr.,
 727 Merchants Exchange Bldg., San Francisco, Cal. '99
 **WUGLER, ANDRE, Min. Engr., Prof. Mining, 7 Rue Viète, Paris, France. '85
 *WUST, FRITZ, Met., Prof. Königl.-Tech. Hochschule, Ludwigs Allee,
 Aachen, Germany. '05
 *WYATT, FRANCIS, Cons. Anal. Chem., 402 West 23d St., New York, N. Y. '87
 *WYATT, JAMES S., Mine Mgr. P. O. Box 9, Sausalito, Cal. '05
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 *WYMAN, GEORGE H., JR., Min. Engr. Wallace, Idaho. '13
 **WYNNE, ASHLEY H. P., Assayer, Care Calabacillas Mining Co.,
 via San José de Garcia, Sinaloa, Mexico. '95
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 363 Locust St., Steelton, Pa. '14
 *YAMADA, NAOYO, Dir., Mitsui Min. Co.,
 23 Nakaroku bancho, Kojimachiku, Tokyo, Japan. '12
 *YAMAGUCHI, KISABURO. 24 Hinokioho Akasakaku, Tokyo, Japan. '10
 *YAMANUCHI, SHIGEMA, Cons. Engr. to Takata & Co.,
 Kojimachi-Ku, Tokyo, Japan. '98
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 36 Sze Chuan Rd., Shanghai, China. '12
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 14 Winchester Ave., Sedgley Park, Prestwick, Manchester, England. '10
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 *YEANDLE, WILLIAM H., JR., Min. Engr., U. S. Smelt., Ref. & Min. Co.,
 411 Edificio de la Mutua, Mexico City, Mexico. '04

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*ZAPFFE, CARL, Min. Geol.....	P. O. Box 93, Brainerd, Minn.	'11
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 Thomas, F. F.
 Turner, R. C.
 Wepfer, G. W.
 Bishop.—Leffingwell, W. H.
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 Dale.—McGee, J.
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 Foote, A. DeW.
 Fraser, W. L.
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 Nye, R.
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 Kervin, J. H.
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 Leach, R.
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 Loughbridge, C.
 McClave, J. M.
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 McMahan, C. H.
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 Miller, D. G.
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 Morse, B. P.
 Noble, L. S.
 Norman, J. E.
 Parker, R. A.
 Patrick, W. B.
 Paul, R. B.
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 Platt, E. H.
 Porter, J. A.
 Porter, W. E.
 Pritchett, C. W.
 Prommel, H. W. C.
 Proske, T. H.
 Prout, J. W., Jr.
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 Richards, J. H.
 Rickard, F.
 Roberts, J. C.
 Robeson, J. H.
 Roesser, F.
 Sanderson, H. S.
 Sayre, H.
 Schneider, G. W.
 Soobey, J. C.
 Searing, L.
 Sears, M. A.
 Sebben, E. W.
 Seemingshaus, G.
 Shumway, R. W.
 Stearns, T. B.
 Swart, W. G.
 Taylor, F. M.
 Timmons, C.
 Titworth, F. S.
 Toll, R. H.
 Troutman, J. H.
 Utley, H. H.
 Vaile, J. F.
 Ward, W. F.
 Walborn, J. F.
 Whitaker, O. R.
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Golden.—Brooke, L.
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 Myers, J. W.
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 Warner, R. K.
 Whitney, E.
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 Kahn, J.
 Keller, H. A.
 Kellogg, L. O.
 Kemp, J. F.
 Kempton, C. W.
 Kennedy, J. E.
 Kennedy, J. J.
 Kennedy, J. S.
 Kent, W.
 Kent, W. St. G.
 Kiliani, R. B. T.
 King, C. F.
 Kirchhoff, C.
 Klepetko, F.
 Knox, H. H.
 Kuns, G. F.
 Kurts, E. L.
 Lamb, R.
 Lancaster, T.
 Lane, J. S.
 Langeloth, J.
 Langton, J.
 Lawrence, B. B.
 Leary, D. J.
 Ledoux, A. R.
 Le Fevre, H. F.
 Leggett, T. H.
 Levy, A. G.
 Lewisohn, J. A.
 Lidner, P. G.
 Loeb, C. M.
 Loomis, E. E.
 Lowy, A.
 Ludlum, A. C.
 Lyman, F.
 McCreery, J. H.
 McCorken, E. P.
 McIlvain, E. M.
 McKinlay, W. B.
 McKinney, R. C.
 MacDonald, M. F.
 Magee, J. F.
 Mannheim, P. A. L.
 Mayer, L. W.
 Meeks, R. V.
 Megraw, H. A.
 Meier, E. D.
 Meikleham, T. M. R.
 Mein, W. W.
 Mentzel, C.
 Mercer, J. W.
 Merriman, M.
 Messiter, E. H.
 Mildon, R. B.
 Millard, H. A.
 Millard, W. J.
 Miller, S.
 Minard, F. H.
 Monell, A.
 Moore, G.
 Moore, R. R.
 Morrow, J. T.
 Morse, W. S.
 Moses, A. J.
 Mosman, P. A.

New York City.—Continued.

Munroe, H. S.
Murray, G.
Naething, F. S.
Nau, J. B.
Neel, C. B.
Newhall, H. B., Jr.
Nichols, W. H., Jr.
Nicholson, F.
Nicoll, B.
Olcott, E. E.
Orr, J. F.
Orrok, G. A.
Page, W. K.
Painter, R. K.
Palmer, C. E.
Patterson, R. C., Jr.
Payne, C. Q.
Peale, R.
Pearson, F. S.
Peele, R.
Perin, C. P.
Perkins, H. C.
Perry, O. B.
Perry, W. A.
Pierce, F. E.
Pitkin, L.
Plate, H. R.
Pollon, H. A.
Poirier, C. H.
Pomeroy, W. A.
Porter, H. H.
Porter, W. H.
Potter, W. C.
Powell, DeV.
Preston, V.
Prindle, E. J.
Prosser, H. A.
Pyne, W. F.
Rand, C. F.
Raymond, R. W.
Read, T. T.
Reed, C. S.
Reed, H. B.
Reno, J. W.
Rice, G. S.
Richardson, C.
Rickard, R. D.
Ricketta, L. D.
Ricketta, P. de P.
Riggs, G. W.
Riordan, D. M.
Robins, T.
Robinson, B. A.
Robinson, C.
Roeder, E. F.
Rogers, A. P.
Rogers, E. M.
Rogers, W. B.
Ropp, A. von der
Roosi, A. J.
Rothschild, C. G.
Rubidge, F. T.
Ruhl, L.
Runyon, W. C.
Ryall, G. M.
Ryan, J. D.
Salas, L. E.
Sanborn, J. F.
Saulles, C. A. H. de
Saunders, W. L.
Schmidt, W. C., Jr.
Schroter, G. A.
Schwab, C. M.
Schwerin, C. M.
Scovill, H. H.
Seaman, H. B.
Seligman, A. J.
Sethna, N. R.
Shanks, D. W.
Sherwood, F. P.
Shipp, E. M.
Shurick, A. T.
Simonds, F. M.
Skinner, E. N.
Smith, C. H.
Smith, E. A. C.

New York City.—Continued.

Smith, E. P.
Smoot, A. M.
Snow, C. H.
Spillsbury, E. G.
Stanton, F. McM.
Stanton, J. R.
Stanton, R. B.
Stanton, W. A.
Stehli, H. J.
Sternfeld, T.
Stewart, J.
Stiles, T. W.
Stone, G. C.
Stoughton, B.
Struthers, J.
Stuts, E.
Sussmann, O.
Tackman, H.
Tainter, F. S.
Thayer, B. B.
Thomas, D. R.
Thomas, K.
Thomas, M. L.
Thompson, R. M.
Thomson, J.
Thornton, W. D.
Tonnelé, T.
Torrey, H. G.
Towl, F. M.
Towns, R. S.
Traylor, S. W.
Tweedy, A. M.
Tyler, N., Jr.
Vail, R. H.
Value, B. R.
Van Arsdale, G. D.
Van Ellis, H. T.
Van Mater, J. A.
Van Sicken, M.
Vogel, F. A.
Vogelstein, L.
Waldo, L.
Walker, A. L.
Walker, W. R.
Waller, E.
Wang, Y. T.
Ward, W. P.
Watkins, T. H.
Watson, R. W.
Webster, H.
Weed, W. H.
Weekes, F. R.
Weir, C. G.
Weid, C. M.
Westervelt, W. Y.
Westlake, E. H.
Wethey, A. H.
Whinery, S.
Wiley, W. H.
Wiley, W. M.
Wilkins, H. A. J.
Williams, A.
Williams, D.
Williams, E. G.
Williams, H. L.
Williams, J. T.
Wilson, E. J.
Wilson, M. O.
Wilson, R. T., Jr.
Wise, S. L.
Wong, W. A.
Wood, E. F.
Woodman, J. E.
Wyatt, F.
Yeatman, P.
Young, E. L.
Zehnder, C. H.
Niagara Falls.—Hall, C. M.
North River.—Hooper, F. C.
Nyack.—Baldwin, W. S.
Pleasantville Sta.—Barratt, S. A.
Port Henry.—Hodgkins, A. R.
Witherbee, F. S.
Witherbee, W. C.
Rochester.—Kneath, W. W.
Scott, D. D.

Rome.—Jenkins, W., Jr.
Eye.—Barron, G. D.
Schenectady.—Capp, J. A.
Hunnings, S. V.
Lyon, G. J.
Pauly, K. A.
Rushmore, D. B.
Van Brunt, C. G.
Whitney, W. R.
Seagate.—Rowand, L. G.
Spyuten Dayvil.—Johnson, E. M.
Standish.—Ross, L. P.
Stony Point.—Wiles, E. L.
Syracuse.—Bellinger, H. P.
Blauvelt, W. H.
Cogswell, W. B.
Handy, H. H. S.
Hasard, F. R.
Neill, W. L.
Pennock, J. D.
Smith, J. W.
Trump, E. N.
Witherby, E. C.
Westbury.—Sharpless, F. F.
West New Brighton.—Miller, D. I.
Witherbee.—Fulton, A. C.
Knowles, S. A.
Yonkers.—Thayer, R. H.

NORTH CAROLINA

Ashville.—Case, B. H.
Hewitt, F. R.
Candor.—Barbour, P. E.
Chapel Hill.—Pratt, J. H.
Charlotte.—Thies, A.
Dillsboro.—Harria, A. L.
Oxford.—Caldwell, H. W.
Salisbury.—Mauney, A. C.
Tucker, A. W.
Stackhouse.—Betta, A. G.

NORTH DAKOTA

Tower City.—Young, C. D.

OHIO

Akron.—Mooney, J. D.
Pikin, S. H.
Cincinnati.—Burke, M. D.
Mescham, D. B.
Waite, H. M.
Cleveland.—Abbott, R. R.
Barren, H. A.
Bartol, G.
Brooks, J. Y.
Brown, H. H.
Cremer, J. H.
Crowell, R.
Croxtan, D. T.
Croxtan, S. W.
Dalton, H. G.
Dunham, L. E.
Emmerton, F. A.
Fisher, G. E.
Fulton, C. H.
Grasselli, C. A.
Hale, H. C.
Hanna, H. M., Jr.
House, A. C.
Jeffries, Z.
Jopling, R. F.
Kaufman, H. L.
Kimmel, H. R.
Knapp, G. F.
Kochler, W.
Lash, H. W.
Lihme, I. P.
McClure, A. P.
McKee, A. G.
McMurray, M.
Mather, S.
Mather, W. G.
Merrill, E. P.
Merry, H. G.

Cleveland.—Continued.

Millard, R. P.
Miller, L. B.
Mohrman, E. M.
Murray, C. B.
Oglebay, E. W.
Peck, F. J.
Pierce, T. E.
Quarrie, B. D.
Rattle, W. J.
Read, J. B.
Richards, F. B.
Roby, L. A.
Sheadle, J. H.
Smith, A. W.
Stebbins, H. S.
Stillwagon, S. C.
Textor, O.
Treat, F. H.
Van Horn, F. R.
Wellman, S. T.
Zeising, R.
Columbus.—Belden, S. B.
Frantz, J. H.
Gard, I. R.
Howald, F.
Linhardt, H. W.
Lovejoy, E.
Ray, F. A.
Wyer, S. S.
Dillonvale.—Stoller, F. E.
East Cleveland.—Cross, E. O.
Elyria.—Boynton, A. J.
Koehler, C. F.
Jackson.—Amesden, F. F.
Lowellville.—Bentley, R.
Middletown.—Carnahan, R. B., Jr.
New Philadelphia.—Smyser, A. E.
Toledo.—Ammon, M. A.
Crowther, J. S., Jr.
Ryan, E. C.
Stubbs, G. W.
Woods, C. L.
Oberlin.—Crafts, W. N.
Warren.—Kirkham, G. D.
Youngstown.—Braman, H. S.
Ford, E. L.
McCleary, E. T.
McDonald, T.
Manning, W. E.
Perry, J. E.
Reese, J. N.
Reinhardt, G. A.
Robinson, C. S.

OKLAHOMA

Bartlesville.—Bell, F. R.
Diescher, A. J.
Rissman, O.
Buck.—Dunkin, D. D.
McAlester.—Rutledge, J. J.
Tonkin, S. J.
Muskogee.—Bradley, O. U.
Nowata.—Logan, W. B.
Oklahoma City.—McKanna, E. A.
Perry.—Hartman, T. F.
Shawnee.—Dodge, W. E.
Tulsa.—McNutt, V. H.

OREGON

Baker City.—Gleeson, W. G.
Melsner, E.
Schumacher, A. J.
Blackbutte.—Harris, W.
Carlton.—Dennis, W. B.
Corvallis.—Parks, H. M.
Swartley, A. M.
Cottage Grove.—Stewart, A. J.
Eugene.—Emmons, C. D.
Homestead.—Anta, E.
Pendleton.—Slusher, D.
Portland.—Cox, W. R.
Elmer, W. W.

Portland.—Continued.

Gallagher, J. H.
Hammer, J. G.
Hammond, I. B.
Keady, L. Y.
Lawrie, H. N.
Lindsey, J.
McAllen, J. L.
Mackay, W.
Pratt, A. F.
Rye Valley.—Dake, W. M.
Springfield.—Henderson, J. McC.
Sumpter.—Baillie, F. S.
Union.—Marr, R. A.

PENNSYLVANIA

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Goundie, J. H.
Greenall, J.
Altoona.—Koch, G. B.
Pease, F. N.
Strand, C. H.
Young, C. D.
Ardmore.—Knapp, I. N.
Siedler, G. J.
Athens.—Abbe, F. R.
Baldwin.—Palmer, I. A.
Bear Creek.—Lewis, A.
Bellevue.—Acker, L. K., Jr.
Bethlehem.—Acker, E. O'C.
Bird, R. M.
Boyd, H.
Cummings, W. L.
Francis, C. W.
Lawshie, V. T.
Leibfried, J. E.
Morris, H. T.
Schropp, A. S.
Birdsboro.—Brooke, D. O.
Brooke, R. E.
Klugh, B. G.
Bitumen.—Miller, G. L.
Braddock.—Dinkey, C. E.
Bryn Mawr.—Ely, T. N.
Jones, L. W.
Burnham.—Skinner, O. C.
Catasauqua.—Fuller, J. W., Jr.
Lawall, C. E., Jr.
Peckitt, L.
Seaman, H. J.
Stillman, J. S.
Thomas, E.
Chester.—Brown, H. J.
Callaghan, J. T., Jr.
Clearfield.—Hess, E. W.
Hinterleitner, H. J.
Coatesville.—Huston, C. L.
Conshohocken.—Logan, J. W.
Wood, R. G.
Cornwall.—Souder, H.
Crafton.—Carpenter, A. H.
Drifton.—Coxe, E. B., Jr.
Dunbar.—Marshall, S. B.
Dunmore.—Bryden, A.
Duquesne.—Diehl, A. N.
East Mauch Chunk.—Sayre, M. F.
Easton.—Elder, G. R.
Fackenthal, B. F., Jr.
Firmstone, F.
Green, C. B.
Hart, E.
Marquard, W. B.
Mitchell, H. H.
Rice, J.
Sherrard, J. M.
Shimer, P. W.
Sweetser, R.
East Pittsburg.—Herr, H. T.
Ellsworth.—Cooper, M. D.
Petty, M. K.
Emaus.—Ormrod, G.
Ormrod, J. D.
Erie.—Hilton, H. G.
Everett.—Thropp, J. E., Jr.

Franklin.—Conradson, P. H.
Germantown.—Morris, R. J.
Graceton.—Lingle, C. M.
Harrisburg.—Boyd, J. Y.

Dull, A. J.
McCormick, H., Jr.
McCormick, V. C.
McCreath, A. S.
McCreath, L.

* Hazleton.—Ayres, W. S.

Bullock, A.
Davies, W. H.
Drake, A. W.
Hoover, W. M.
Houck, C. B.
Jones, J. E.
Jones, T. D.
Lewis, A. H.
Markle, A.
Pardee, I. P.
Heliwood.—Dowler, H. P.
Hokendauqua.—Hulick, C. E.
McKee, W. C.
Hollidaysburg.—McLanahan, J. K.
McLanahan, J. K., Jr.
Jeddo.—Jessup, A. B.
Markle, J.
Johnstown.—Crichton, A. B.
Graham, H.
Howe, C. L.
McDonald, J. A.
Marshall, S. McC.
Moore, M. G.
Stackhouse, D. M.
Thackray, G. E.
Thompson, F. E.
Wolfe, H. C.
Kingston.—Caruthers, A. W.
Davis, H. G.
Lansford.—Crankshaw, H. M.
Dorrance, C., Jr.
Ludlow, E.
Nold, F. B.
Whildin, W. G.
Lancaster.—Stewart, J. B.
Lebanon.—Coleman, B. D.
Lee, R. H.
McKeechnie, B. E.
Weimer, A. A.
Weimer, E. A.
Wolfe, W. L.
McKeesport.—Cornelius, W. A.
Crawford, R. C.
Mauch Chunk.—Lents, W. O.
Midland.—Badlam, S.
Minersville.—Neale, J. B.
Randall, D. V.
Morris Run.—Morgan, C. G.
Mount Carmel.—Righter, T. M.
Munhall.—Eynon, D. L. L.
Nanticoke.—Kohlbraker, F. H.
New Castle.—Cunningham, P. H.
Johnson, C. H.
Newtown.—Hutchinson, E. S.
Norristown.—Hartnft, S. S.
Oakmont.—Soafie, W. B.
Oliver.—Keighley, F. C.
Osceola Mills.—Good, G. McC. H.
Palmerton.—Gearhart, F. B.
Grubnau, V. C.
Rigg, G.
Singmaster, J. A.
Sinn, F. P.
Parkesburg.—Beale, H. A., Jr.
Parryville.—Freeman, S. S.
Osborn, A. A.
Philadelphia.—Adams, H. C.
Aertson, G.
Angerer, V.
Bache, F.
Baer, G. F.
Barringer, D. M.
Birkinbine, J.
Blair, A. A.
Brown, A. P.

Philadelphia.—Continued.

Burnham, W.
 Chance, H. M.
 Clamer, G.
 Clark, C. M.
 Clark, W.
 Clement, F. H.
 Clymer, E. T.
 Conner, E. T.
 Corbin, J. R.
 Cox, E. J. D.
 Crane, T. I.
 Davis, G. C.
 Dilworth, J. B.
 Dimmick, F. D.
 D'Inville, E. V.
 Dixon, A. F.
 Dodge, J. M.
 Du Bois, H. W.
 Dwight, E. W.
 Eynon, T. M.
 Fairchild, S. E.
 Felton, E. C.
 Firmstone, H.
 Fisher, T.
 Flagg, S. G., Jr.
 Garrison, F. L.
 Gatzmer, W. C.
 Gilman, W.
 Haldeman, H. L.
 Hamilton, S. H.
 Harvey, W. S.
 Hearn, W. W.
 Heckscher, L.
 Hess, H.
 Hiles, J. T.
 Hinchman, C. S.
 James, W. M.
 Keeley, F. J.
 Keith, N. S.
 Lavery, V. M.
 Lineaweaver, H. H.
 London, C. J.
 Lyman, B. S.
 McCallum, W. H.
 Mollvain, J. G.
 Maignen, P. A.
 Miles, J. B.
 Mitchell, R.
 Morris, W. H.
 Neilson, W. C.
 Penrose, R. A. F., Jr.
 Perry, R. S.
 Peters, R.
 Reeves, D.
 Rehfuess, W. C.
 Riley, L. A.
 Roberts, F. C.
 Roberts, P. J.
 Salom, P. G.
 Sanborn, E. H.
 Sanders, R. H.
 Smith, W. F.
 Spurr, J. E.
 Stevens, M.
 Stevenson, A. A.
 Strobel, V. O.
 Swank, J. M.
 Taylor, L. H., Jr.
 Thomas, T. L.
 Vauclain, S. M.
 Warriner, S. D.
 Webster, P. W.
 Webster, W. R.
 Williams, M.
 Wolf, O. C.
 Wood, G. R.
 Wood, S.
 Wood, W.
 Wright, W. L.
Philipsburg.—Dunkle, G. F.
Phoenixville.—Harden, J. H.
 MacCallum, N. E.
Pine Forge.—Bailey, J. B.
Pittsburg.—Allderdice, T.
 Armstead, D. McP.
 Bailey, C.

Pittsburg.—Continued.

Baggaley, R.
 Beeken, L. L.
 Black, R. M.
 Braddock, H. F.
 Brown, J. T.
 Burns, W. J.
 Chancellor, W. C.
 Clapp, F. G.
 Clapp, G. H.
 Coffin, W. C.
 Collins, J. P.
 Crabtree, F.
 Darsie, J.
 Davis, S. A.
 Deike, G. H.
 Donner, W. H.
 Dougherty, J. W.
 Eshelman, S. K., Jr.
 Field, H. E.
 Frick, H. C.
 Gittins, A. W.
 Goodale, S. L.
 Graybill, J. H.
 Griswold, C. T.
 Hood, O. P.
 Huntley, L. G.
 Imhoff, W. G.
 Jones, L. M.
 Jones, W. L.
 Kann, M. M.
 Kann, W. L.
 Kennedy, J.
 Luce, W. A.
 Lyon, D. A.
 McDowell, J. C.
 McGrew, E.
 McNaughton, D. W.
 Meller, H. B.
 Messler, E. L.
 Mesta, G.
 Miller, C. L.
 Morganroth, L. C.
 Morrison, J. S.
 Morrison, T.
 Page, G. S.
 Patterson, P. C.
 Phillips, F. C.
 Plock, A. F.
 Potter, W. S.
 Ray, H. C.
 Rea, W. H.
 Rice, G. S.
 Rys, C. F. W.
 Sargent, G. W.
 Scaife, J. V.
 Scaife, W. L.
 Scott, J.
 Seaver, K.
 Shiras, W. McG.
 Smith, H. I.
 Smith, L. B.
 Snelling, W. O.
 Speller, F. N.
 Taylor, E. J.
 Taylor, S. A.
 Tiemann, H. P.
 Toy, F. L.
 Wadsworth, M. E.
 Walter, B.
 Wilkins, W. G.
 Willard, J. O.
 Wood, T. D.
 Woodworth, R. B.
Pittston.—Law, J. B.
 Owens, W. D.
Plymouth.—Evans, M. R.
Port Carbon.—Allison, R.
Pottstown.—Cook, E. B.
 Cook, E. S.
 Hartshorne, J.
 Hobart, S. O.
 Potts, G. H.
 Roe, J. P.
Pottsville.—Althouse, H. W.
 Archbald, J., Jr.
 Cullum, J. B.

Pottsville.—Continued.

Herdon, E. L.
 Hill, F. A.
 Luther, E. C.
 Richards, W. J.
 Shearer, A. W.
 Primos.—Stein, W. M.
Puaxsutawney.—Cook, J. B.
 Furniss, T. A.
 McLeavy, J.
 Rankin.—Berg, H. A.
Reading.—Bower, C. P.
 Broden, A.
 Kunhardt, W. B.
 Mollvain, W. R.
 Pendleton, J. S.
 Quier, E. A.
 Smink, F. C.
Republic.—Zeller, H. P.
Riddlesburg.—Lauder, W.
 Ross, E. P.
Robesonia.—Kramer, J. F.
 Patterson, S. B.
St. David's.—Lyle, D. A.
Schuylkill-Haven.—Ginder, W. H. H.
Scottdale.—Oberly, A. D.
 Stratton, W. C.
Scranton.—Archbald, H.
 Belin, H., Jr.
 Boyle, C., Jr.
 Bryden, C. L.
 Davis, M., Jr.
 Duck, G. F.
 Engel, G. W.
 Foster, R. J.
 Gleason, F. A.
 Griffith, W.
 Jones, E. S.
 Law, A. F.
 Lawrence, W. L.
 Leaning, E. H.
 Mattes, W. F.
 Parke, W. G.
 Petebone, E. R.
 Platt, F. E.
 Platt, F. J.
 Richmond, W. H.
 Scranton, W. W.
 Simpson, C. D.
 Stevenson, G. E.
 Storrs, A. H.
Sharon.—Brayer, N. G.
 Buhl, F. H.
 McClure, S.
 Stevenson, J., Jr.
 Thomas, J. F.
Sharpsville.—Collord, G. L.
 Pierce, J. B.
Sheridan.—Chauvenet, S. H.
Snow Shoe.—Snyder, W. C.
Somerset.—Krebs, G. J.
South Bethlehem.—Buck, C. A.
 Cahen, J. P., Jr.
 Callen, A. S.
 Colby, A. L.
 De Saulles, A. B.
 Drinker, H. S.
 Dunbar, D. M.
 Eckfeldt, H.
 Grace, E. G.
 Johnston, A.
 Jordan, R. D.
 Krause, W. B.
 Liebig, J. O.
 Long, J. S.
 Michel, R. E.
 Miller, B. Le R.
 Merwin, M. H.
 Richards, J. W.
 Shimer, W. R.
 Snyder, H. S.
 Wilbur, W. A.
State College.—Crane, W. R.
 Pallister, H. D.
Steeltown.—Carney, F. D.
 Davis, W. W.

Steelton.—Continued.

Little, J. E.
 McKay, R. V.
 Reynders, J. V. W.
 Turner, C. P.
 Yake, E. E.
 Torridale.—Saunders, W. E.
 Towanda.—Lawrence, Schuyler.
 Tyrone.—Bachart, A. E.
 Uniontown.—Peters, R., Jr.
 Willard, L. L.
 Wright, C. O.
 Vandergrift.—Beale, A. H.
 Verona.—Miller, H. F.
 Villanova.—Saxman, E. F.
 Wawa.—Hibbs, J. G.
 West Chester.—Baird, H. J. B.
 White Mills.—Dorflinger, C. H.
 Wilkes-Barre.—Ashley, H. H.

Bridgman, J. C.
 Bunting, D.
 Chance, E. M.
 Chase, F. M.
 Dodge, W. F.
 Enxian, C.
 Huber, C. F.
 Humphrey, J. M.
 Lawall, E. H.
 Lloyd, J.
 McMahon, F. J.
 Newbaker, E. J.
 Nicholson, S. T.
 Norris, R. Van A.
 Otto, H. H.
 Quin, R. A.
 Seip, R. H.
 Stearns, I. A.
 Sterling, P.
 Welles, T. L.
 Zerby, F. E.
 Wilkesburg.—Harpor, H. S.
 Kerr, D. G.
 Murphy, E. M.
 Prince, E.

Williamsport.—Ahles, R. L.
 Windber.—Denman, H.
 Woodlawn.—Maltits, E. von
 Wyebooke.—Potts, W. M.

PHILIPPINE ISLANDS

Aororoy.—Wilmot, H. C.
 Cadiz.—Nichols, J. C.
 Manila.—Pratt, W. E.

PORTO RICO

San Juan.—Holmes, F. C.

RHODE ISLAND

Newport.—Emmons, A. B.
 Howe, E.
 Richards, E.
 Providence.—Pitman, S. M.

SOUTH CAROLINA

Clinton.—Seafie, H. L.
 Columbia.—Taber, S.
 Georgetown.—Boyt, J.
 Darlington, W.

SOUTH DAKOTA

Deadwood.—Vincent, H. S.
 Hill City.—Overpeck, A. C.
 Lead.—Blackstone, R.
 Clark, A. J.
 Grier, T. J.
 Hers, N.
 Manion, E.
 Ross, A. J. M.
 Schnitzel, H.
 Sharwood, W. J.
 Yates, B. C.
 Rapid City.—Crook, W. J.
 Fahrenwald, F. A.

Rapid City.—Continued.

Halley, A. S.
 O'Harra, C. C.
 Trojan.—Bowman, F. C.

TENNESSEE

Bristol.—Puckette, S. E.
 Cardiff.—Tarwater, P.
 Chattanooga.—Carter, T. E.
 Chamberlain, H. S.
 Chamberlain, M.
 Colyar, L. S.
 James, C. E.
 James, W. T.
 Lesley, T. H.
 Lesley, W. M.
 Maynard, T. P.
 Soper, E. C.
 Copperhill.—Caine, M. A.
 Risque, J. B.
 Isabella.—Renwick, C. W.
 Johnson City.—Howe, F. P.
 Kemler, W. H.
 Knoxville.—Blow, A. A.
 Jarvis, R. P.
 Rodgers, G. B.
 La Follette.—Coze, E. H.
 Crowe, L. C.
 La Follette, H. M.
 Mascot.—Wise, A. L.
 Memphis.—Reid, J. W.
 Mt. Pleasant.—Davison, G. L.
 Nashville.—Dudley, W. L.
 Glenn, L. C.
 Purdue, A. H.
 New Market.—Underhill, W. A.
 No. Chattanooga.—Bowron, M.
 W.
 Petros.—Livingston, I.
 Rockwood.—Clymer, F. H.
 Wind Rock.—Hutcheson, W. C.

TEXAS

Austin.—Phillips, W. B.
 Beaumont.—Wilson, N. R.
 Blessing.—Le Wald, E. A.
 Corpus Christi.—Hammer, W. L.
 Corsicana.—Lee, M. P.
 Danbury.—Kedzie, G. E.
 Eagle Pass.—Jones, E. R.
 Scheble, M. C.
 El Paso.—Adams, A. K.
 Bradley, D. H., Jr.
 Camphus, G. A.
 DeVore, E. H.
 Drury, W. M.
 Farrar, B. L.
 Gordon, W. D.
 Hamilton, F. C.
 Harms, E.
 Hutchinson, R. B.
 Manahan, R. F.
 Ormsbee, J. J.
 Parker, M. B.
 Pomeroy, W. E.
 Reckhart, D. W.
 Rose, W. W.
 Small, W. N.
 Torres, F. L.
 Wright, L. A.
 Fort Worth.—McCart, R., Jr.
 Shaw, J. S.
 Houston.—Dumble, E. T.
 Hager, L.
 Maria.—Hubbard, H. J.
 Marshall.—Turner, N. P.
 San Antonio.—Goddicke, C.
 Newell, G. S.
 Seta, G.
 Sprout, A. D.
 Tuttle, A. L.
 Wentworth, I. H.
 Wines, J. M.
 Shafter.—Burcham, W. D.
 Gleim, E. M.
 Terlingua.—Koch, W. E.

UTAH

Alta.—Fisher, W. B.
 Portugal, J. H.
 Bingham Canyon.—Barnes, W. A.
 Carnahan, T. S.
 Daley, M. J.
 Deshler, G. O.
 Kinney, H. D.
 Rood, V. S.
 Sears, S. C.
 Stiebel, H. J.
 Clear Creek.—Hill, F. C.
 Eureka.—Fitch, W.
 McChrystal, J. H.
 Frisco.—Hendrickson, W. H.
 Shaw, S. F.
 Garfield.—Engelhardt, E. C.
 Hansen, F.
 Hawley, R. H.
 Hogarty, B.
 Gunlock.—Lemmon, D.
 Lark.—Cole, W. B.
 Marysville.—Trauerman, C. J.
 Murray.—Adams, C. W.
 Hyde, R. W.
 McIntosh, J. B. S.
 Richard, B. N.
 Neelen.—Thomas, W. S.
 Newhouse.—Heidenreich, W. L.
 Ophir.—Clark, E. W.
 Park City.—Humes, J.
 Sherman, F. W.
 Salt Lake City.—Anderson, F.
 Austin, L. S.
 Bardwell, A. F.
 Blood, G. D.
 Bodfish, F. V.
 Bradford, R. H.
 Callow, J. M.
 Chapman, R. D.
 Cowans, F.
 Daggett, E.
 Dick, J. C.
 Doolittle, C. H.
 Duffield, M. S.
 Ellerbeck, T. R.
 Ellis, H. R.
 Frank, A.
 Gayford, E.
 Gemmell, R. C.
 Gunn, G. E.
 Hamman, J. S.
 Hanchett, L.
 Hansen, G. T.
 Hart, V. A.
 Heikes, V. C.
 Howard, W. H.
 Jackling, D. C.
 Jeffs, L. A.
 Jennings, E. P.
 Johnson, E. W.
 Johnson, M. M.
 Jones, E. B.
 Keeney, R. M.
 Kirk, M. P.
 Krumb, H.
 Lavagnino, G.
 Leavell, J. H.
 Lewis, R. S.
 Lundberg, J.
 McCaskell, J. A.
 McKim, J. W.
 MacViechie, D.
 Mixer, C. T.
 Moore, C. F.
 Nebeker, W. G.
 Newhouse, S.
 Riter, G. W.
 Riter, L. E., Jr.
 Thomson, H. N.
 Tibby, B. F.
 Tiernan, A. K.
 Van Winkle, C. T.
 Wall, E. A.
 Weir, T.
 Whitley, C. W.

Salt Lake City.—Continued.

Williams, F. T.
Wilson, G. B.
Wilson, W. A.
Winwood, J. H.
Wraith, W.
Zalinski, E. R.
Scranton.—Nebeker, A. C.
Tooele.—Day, A. M.
Kilbourn, W. D.
Rule, J. A.

VERMONT

Poultney.—Shutts, A. B.
Randolph.—Hollis, C. B.
Woodstock.—Williams, E. H., Jr.

VIRGINIA

Austinville.—Borchardt, W. O.
Big Stone Gap.—Hodge, J. M.
Peck, W. R.
Blacksburg.—Burkhart, O. C.
Holden, R. J.
Buchanan.—Pechin, E. C.
Charlottesville.—Watson, T. L.
Covington.—Parrish, R. L.
Darbyville.—Thompson, C. H.
Glamorgan.—Cheyney, J. S.
Glen Wilton.—Doak, S. E.
Hudson, J. B.
Lantana.—Knutsen, T.
Leesburg.—Grammer, F. L.
Grammer, W. S.
Janney, T. G.
Lignite.—Stull, J. W.
Low Moor.—Humbert, F. U.
Lipscomb, R. A.
Means, E. C.
Lynchburg.—Taylor, W. W.
Norfolk.—Wadleigh, F. R.
Pennington Gap.—Shoemaker, G. M.
Pocahontas.—Stow, A. H.
Wright, H. B.
Pulaski.—Hill, R. F.
Richmond.—Froehling, H.
Gay, W. B.
Jones, C. Ap. C.
Moore, W.
Scarborough, F. W.
Sullivan, W. P.
Roanoke.—Coe, W. W.
Wallis, F.
Staunton.—Catlett, C.
Tazewell.—Williams, J. P.
University.—Grasty, J. S.
Virgilina.—Lassiter, R. G.
Warrenton.—Fell, E. N.
West Norfolk.—Hamilton, E. H.
Wytheville.—Corsa, D.
Hicks, C. M.

WASHINGTON

Bellingham.—Phoenix, C. E.
Everett.—Butler, W. C.
Loomis.—Limbach, E. C.
Northport.—Shedd, S.
Pullman.—Robbins, H. R.
Thomson, F. A.
Republic.—Marsh, R.
Morse, E. C.
Richardson, S. H., Jr.
Sharp, B. N.
Woodhouse, C. C., Jr.
Seattle.—Blair, A. F.
Boyle, H.
Burley, C. R.
Butler, M. C.
Collins, G. A.
Dahl, O. R.
Daniels, J.
Dunn, R. I.
Evans, G. W.

Seattle.—Continued.

Fogh, H. F.
Gray, E. F.
Hill, F. A.
Jayne, A. R.
Kennedy, A.
Kleesattel, R.
Landes, H.
Laucks, I. F.
Lee, C. F.
Lewis, C. M.
McLeod, H. D.
Manley, H. L.
Mathews, E. J.
Potter, E. C.
Powell, F.
Roberts, M.
Rodgers, J. H.
Simenstad, C.
Slater, A.
Stephen, W. M.
Teel, W. H.
Weaver, C. E.
Spokane.—Armstrong, L. K.
Bailey, F. C.
Bird, F. H.
Boyd, A. W.
Burbridge, F.
Clarke, R. H.
Goodsell, C. H.
Haas, J. C.
Holmes, R. G.
Kehoe, H.
Linney, W. H.
Newton, H. W.
Paterson, A. W.
Porter, J. McD.
Ralston, J. C.
Rea, J. E.
Richards, J. V.
Riebel, O. F.
Robbins, C. P.
Roberts, E. J.
Ross, F. A.
Sonnemann, G. A.
Spalding, E. P.
Tate, E. L.
Tacoma.—Chase, R. E., Jr.
Claghorn, C. R.
Greensfelder, N. S.
Levensaler, L. A.
Morse, W. V.
Pott, J. N.
Tarr, R. F.

WEST VIRGINIA

Ansted.—Page, E. R.
Benwood.—Wood, W. O.
Bluefield.—Claggett, T. H.
Stewart, John
Bramwell.—Buck, S. M.
Carbon.—James, W. E.
Charleston.—Anderson, J. K.
Borden, G. S.
Clark, J. M.
Cunningham, J. S.
Krebs, C. E.
Eagle.—Atkinson, L. W.
Eckman.—Cunningham, F. E.
Schofield, W. McN.
Elkhorn.—Lincoln, J. J.
Tierney, J. J.
Eugene.—Martin, R. L., Jr.
Evenwood.—Raine, J. M.
Fairmont.—Haas, F.
Moore, E. B.
Rightmire, R. E.
Smyth, J. G.
Fire Creek.—Blackburn, H. H.
Gary.—Evenson, H. N.
O'Toole, E.
Saunders, H. W.
Glen Jean.—Nichol, T.
Glen White.—White, E. E.
Huntington.—Kent, J. F.
Jodie.—Marshall, J. J.

Kanawha Falls.—Roeser, E. B.
Landgraf.—Ord, W. D.
Lost Creek.—Leisenring, A. C.
Macdonald.—Dixon, S.
Thomas, P. C.
Morgantown.—Greer, H. C.
White, I. C.
Powellton.—Powel, G. H.
Powhatan.—Tierney, L. E.
Red Jacket.—Cummins, W. N.
Rose Siding.—McNulty, S. G.
Slab Fork.—Caperton, W. G.
Sprigg.—Beddall, T. H.
Stanford.—Binford, C. M.
Vivian.—Patterson, G. S.
Ward.—Grossan, C. C.
Wheeling.—Hearne, D. G.
Hearne, J. G.
Stalnaker, R.
Williamson.—Mannakee, N. H.
Worth.—Brooke, H.

WISCONSIN

Appleton.—Bagg, R. M.
Orbison, T. W.
Ashland.—Wilkins, W.
Cudahy.—Hamilton, J. P.
Hazel Green.—Strasser, W. F.
Hurley.—Hardenburgh, L. M.
Royce, S.
Granton.—Scoles, J. C.
Madison.—Holden, E. C.
Leith, C. K.
Newell, A.
Van Hise, C. R.
Wheelwright, O. W.
Winchell, A. N.
Mayville.—O'Connor, E. S.
Phibbs, W. R.
Milwaukee.—Hamilton, J. P.
Hulst, N. P.
Nordberg, B. V.
O'Neill, F. W.
Schlesinger, F.
Montreal.—Price, J. M.
Platteville.—Estabrook, E. L.
Racine.—Wilson, G. B.

WYOMING

Cheyenne.—Bardlett, A. B.
Jaramis, C. E.
Laramie.—Boyle, A. C., Jr.
Thermopolis.—Freeman, G. N.
Wiley.—Harrison, T. S.

CANADA**ALBERTA**

Calgary.—Coste, E.
Foster, G. C.
McNeill, W. F.
Stockett, L.
Drumheller.—Holden, J. O. E.
Lethbridge.—Livingstone, R.
Pocahontas.—Morris, R. H.
Morse, G. H.
Strathmore.—Stockton, R. S.

BRITISH COLUMBIA

Anyox.—Bone, A. J.
Ward, E. E.
Barkerville.—Bailey, M.
Chemainus.—Banon, H. C.
Cranbrook.—Pollen, C. H.
Duncan.—Wallis, H. B.
Wood, T. A.
Ferguson.—Merry, F. C.
Gateway.—Smith, A. H.
Golden.—Brady, J.
Greenwood.—Bell, W. L.
Brunton, F. K.
Keffer, F.
Lachmund, O.

Hosmer.—Thorne, B. L.
 Kamloops.—Batchelor, O. S.
 Kaslo.—Zwicky, W. E.
 Manson.—Otterson, G. W.
 Nelson.—Gracey, A. H.
 Revell, G. E.
 North Vancouver.—Goldworthy, J.
 Penticton.—Stevens, B.
 Princeton.—Kitson, H. W.
 Riondel.—Fowler, S. S.
 Rossland.—Claudet, H. H.
 Loux, C. H.
 Silverton.—DeLashmott, I.
 Skeena Crossing.—Williams, D. J.
 Three Forks.—Norrie, W. G.
 Trail.—Davis, A. W.
 Stewart, R. H.
 Vancouver.—Carry, H. E. C.
 Cleveland, E. A.
 Haggen, E. A.
 Hedley, R. A.
 Hepburn, A. E.
 Kirkpatrick, G. H.
 Knight, E. C.
 Larson, A. G.
 Laselle, B. A.
 Leckie, J. E.
 Leckie, R. G. E.
 Prentice, R.
 Sharp, A.
 Thomson, R. W.
 Townsend, N. F.
 Verrill, C. S.
 Verschoyle, W. D.
 Warden, B. R.
 Wolff, M. A.
 Victoria.—Brewer, W. M.
 Brindle, A. St. C.
 Clark, H.
 Musgrave, R.
 Robertson, W. F.
 Sutton, W. J.

NEWFOUNDLAND

Wabana.—Cavanagh, J. L.
 McCunn, G. B.

NOVA SCOTIA

Glace Bay.—Revere, J. W.
 Halifax.—Graham, S. N.
 New Glasgow.—Cantley, C. L.
 Cantley, T.
 Chambers, R. E.
 Sydney.—Burchell, H. C.
 Lucas, F. E.
 MacDonald, A. W.
 Truro.—Jennison, W. F.
 West Merigomish.—Spence, H. C. E.

ONTARIO

Almonte.—Bell, J. M.
 Aura Lake P. O.—Robbins, P. A.
 Brantford.—Jackson, J. H.
 Cobalt.—Bailey, A. C.
 Brown, A. H.
 Cohen, S. W.
 Cole, A. A.
 Fisher, N. R.
 Hendricks, G. F.
 Johnston, J.
 Jones, T. R.
 Kee, H. A.
 Ledyard, L. W.
 Lyman, R. H.
 Watson, R. B.
 Coniston.—Corless, C. V.
 Copper Cliff.—Agnew, John L.
 Nicholls, J. C.
 Parsons, L. A.
 Patchell, F. J.
 Silvester, G. E.

Halleybury.—Grover, M. B.
 Hay, A. M.
 Henrotin, C. M.
 Hotchkin, M. W.
 Hurd, W. E.
 John, D.
 Rice, J. A.
 Smith, S.
 Stonestreet, G. D.
 Hamilton.—Hobson, R.
 Iroquois Falls.—Pullen, E. F.
 Kingston.—Kirkpatrick, S. F.
 Weigel, W. M.
 Kingsville.—Webb, W. M.
 London.—Culbert, J. V.
 Magpie Mine.—Hasselbring, A.
 Naughton.—Brigstocke, R. W.
 Northpines.—Smythe, H. V.
 Ottawa.—Baker, H. C.
 Bell, R.
 Brock, R. W.
 Cole, L. H.
 Frechette, H.
 Haanel, B. F. C.
 Wilson, A. W. G.
 Sautika.—Randall, C. A.
 Schumacher.—Summerhayes, M. W.
 Sellwood.—Jordan, F. A.
 Silver Centre.—Evered, N. J.
 South Porcupine.—Ashmore, E. P.
 Crowley, T. I.
 Meek, H. C.
 Rodgers, C. E.
 St. Catharines.—Leonard, R. W.
 Sudbury.—Hibbert, E.
 Lunn, R. Jr.
 Timmins.—Humphrey, C.
 Toronto.—Astley, J. W.
 Clark, J. M.
 Corkill, E. T.
 Fernow, B. E.
 Ferrier, W. F.
 Flaherty, R. H.
 Forbes, D. L. H.
 Gibson, T. W.
 Guess, G. A.
 Haultain, H. E. T.
 Hore, R. E.
 Jackman, H. E.
 Kerr, D. G.
 Kirkegaard, P.
 Knight, C. W.
 Lamb, R. B.
 Longwell, A.
 Loring, F. C.
 McAllister, J. E.
 McMaster, A. T. C.
 Miller, W. G.
 Morrison, W. J.
 Morrison, W. L.
 Scott, O. N.
 Segsworth, W. E.
 Smith, A. H.
 Sullivan, A.
 Tyrrell, J. B.
 Willmott, A. B.
 Trenton.—Mottet, W. D. B., Jr.

QUEBEC

Bergerville.—Rhodes, F. B. F.
 Eustis.—Passow, F. M.
 Montreal.—Adams, F. D.
 Bell, J. W.
 Drummond, J. J.
 Drummond, T. J.
 Fergie, C.
 Fisher, H. T.
 Hardman, J. E.
 Hart, P. E.
 Porter, J. B.
 Ross, J. G.
 Russel, H. Y.
 Stansfield, A.
 Whittier, C. C.

Quebec.—Dean, A. L.
 Macaulay, R. M.
 Weedon.—Kohlberg, H. S.
 Westmont.—Adams, W. C.
 Barlow, A. E.

SASKATCHEWAN

Radisson.—Clement, H. E.

YUKON TERRITORY.

Dawson.—Thomas, C. A.
 White Horse.—Marsh, H. W.

MEXICO.

AGUASCALIENTES

Aguascalientes.—Newman, B.

CHIHUAHUA

Batopilas.—Smith, F. D. G.
 Chihuahua.—Eaton, A. L.
 Cusiuhirachic.—Crossette, M. F.
 Parral.—Hambleton, J. W.
 Harrison, W. S.
 Macfarlane, R. W.
 Santa Barbara.—Nagel, F. J.
 Santa Eulalia.—Brinker, A. C.
 Fink, W. N.

COAHUILA

Saltillo.—Carr, P. E. O.]
 Rodriguez, J. C.
 Torreon.—Rone, L. A.

DURANGO

Birimoa.—Cook, E. H.
 Durango.—Wilson, G.
 Gabriel.—Jeffrey, R. H.
 Gomez Palacio.—Stoeffel, P. X.
 Ojuela.—Weniger, R.
 Pedriceña.—Auer, C. I.
 Promontorio.—Bunker, C. E.
 San Dimas.—Caldwell, F. B.
 Goetter, F. B.
 Rawlings, S. L.
 Topia.—Lawrence, T. J.
 Rubel, M. L.
 Velardena.—Adams, R. E.

FEDERAL DISTRICT

Mexico City.—Adams, H.
 Anderson, R. H.
 Babb, P. A.
 Barker, H. A.
 Batchellor, S.
 Braschi, V. M.
 Buchanan, W. C.
 Bucher, L.
 Bullock, L. N. B.
 Chevrillon, L.
 Chippendale, A.
 Cosgro, J. P.
 Dieffenbach, H. M.
 Du Bois, E.
 Ellis, R. W.
 Girault, E.
 Grothe, A.
 Heberlein, K. B.
 Helm, J. D.
 Hochschild, M.
 Hoffmann, K. F.
 Kane, J. I.
 Kleinschmidt, C.
 Kuryla, M. H.
 McCarty, G. J.
 Martinez, A.
 Newcomb, C. S.
 Ordonez, E.
 Raymond, R. M.
 Reynoso, J. J.
 Robinson, H. O.

Mexico City.—Continued.

Ryder, T. J.
Sellerier, C.
Spence, G.
Swain, H. L.
Van Zwailuwenburg, A.
Warne, H. H.
Yeandle, W. H., Jr.

GUANAJUATO

Guanajuato.—Aguilar, P.
Ambrosius, C. E.
Ambrosius, J. R.
Bryant, G. W.
Butler, J. S.
Furness, D.
Herr, I.
MacDonald, J.
Meiklejohn, D. F.
Munro, D. M.
Rhow, J. W.
Smith, H. P.
Wherry, H. P.

HIDALGO.

Pachuca.—Barnum, W. E.
Calland, D. S.
Lendero, C. F. De.
Ough, S. W.
Rose, H.
Solomon, T.
Stockdale, A. H.
Real del Monte.—Wilkinson,
B. A.

JALISCO

Bolanos.—Oldfield, F. W.
Guadalajara.—Dick-Cleland, A.
F.
Slattery, M. J.
Hostotipaquillo.—Hoadley, C. B.
Pentland, W. J.
Thomson, E.

MEXICO

El Oro.—Aldasoro, A.
Allan, T. A.
MacCoy, F.
Main, A. F.
Minsch, W. C.
Rhodes, C. E.
Temascaltepec.—Beard, J. W.

MICHOACAN

Anganguaco.—Edelen, A. W.

NUEVO LEON

Monterey.—Austin, J. F.
Brennon, J. C.
Bridge, S. D.
Carnahan, J. S.
Chase, F. D.
Fairchild, S. A.
Mais, J.
Schmidt, H. C.
Tuschka, O.
Villadama.—Salisbury, E. F.

OAXACA

Oaxaca.—Clark, M.
Comings, G. R.
Woods, F. J.
Sola de Vega.—Gee, E.
Taviche.—Hamilton, C. A.

PUEBLA

Aire Libre.—Cromwell, R. H.
Saunders, T. S.
Puebla.—Brinsmade, R. B.

SAN LUIS POTOSI

Matchuala.—Grabill, C. A.
Rioverde.—Galan, C. F.
San Luis Potosi.—Alexander, C.
Brown, D. C.
Cuevas, L. G.
Dingwall, W. B. A.
Ipsa, R.
Koelle, C.
Williams, J. M., Jr.

SINALOA

Puerto.—Tay, E. A. H.
Masatlan.—Spera, E. L.
Rosario.—Faneuf, S. C.
San Jose de Garcia.—Wynne,
A. H. P.

SONORA

Cananea.—Elasing, M. J.
Trischka, C.
Chivatera.—Duffin, J.
Esqueda.—Mishler, R. T.
Fundicion.—Kirkland, T. C.
Hermosillo.—Hart, C. R.
Nacozari.—Hamilton, H. T.
Hyder, C. A.
Williams, J. B.
Nogales.—Sandoval, P.
Pilares de Nacozari.—Hedges,
J. H.
Mosier, MoH.
Triplett, W. H.
Yzabal.—Budrow, L. R.
Heron, C. L.

TAMAULIPAS

Tampico.—Chamberlain, J. R.
Hayes, C. W.

TEPIC

Irlian del Rio.—Baird, L.
Hackett, W. H.

VERA CRUZ

Minatitlan.—Laurie, F. C.
Orizaba.—Stacpoole, S. W.
Tuxpam.—Payne, A. C.

ZACATECAS

Concepcion del Oro.—Brooks,
J. McMc., Jr.
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 Freeman, A. W.
 Gould, H. J.
 Kirkcaldy, N. M.
 Longworth, W.
 Mingaye, J. C. H.
 Moffat, J.
 Paul, F. P.
 Power, F. D.
 Robertson, J. R. M.
 Savage, A. E.
 Shaw, J. B.
 Smith, G.
 Somerset, H. St. J., Jr.
 Stephen, A. E.
 Wilson, J. B.
 Tent Hill, via Deep Water.—
 Reid, J. H.
 Woolwich.—Mackenzie, G. S.

NEW ZEALAND

Auckland.—Gordon, H. A.
 Rhodes, C.
 Williams, R. E.
 Dunedin.—Beal, L. O.
 Karangahake.—Stansfield, H.
 Nelson.—Briggs, W. A. J.
 Opetiki.—Rhodes, F. N.
 Waihi.—Banks, E. G.
 Grace, W. F.
 Jarman, A.

QUEENSLAND

Brisbane.—Kingsbury, H. C.
 Chillagoe.—Horsburgh, J.
 Mainwaring, H. M. C.
 Cloncurry.—Corbould, W. H.
 Irvinebank.—Raleigh, J. R.
 Lancelot.—Pearce, W. C. W.
 Mareeba.—Gippe, F. de V.
 Mount Morgan.—Boyd, A. A.
 Goode, E. N.
 Moule, J. W.
 Patterson, B. G.
 Richard, G. A.
 White, N. F.
 Silver Spur.—Hall, E.

SOUTH AUSTRALIA

Adelaide.—Gartrell, H. W.
 Hawker, E. W.
 Malvern.—Eustice, R.
 Moonta.—Aplin, W.
 Hayes, W. H.
 Trenerry, E. J.
 Port Pirie.—Jobson, J.
 Poage, J. G.
 Prospect.—Opie, N.
 Wallaroo.—Brown, A. L.
 Dawbarn, G. J.
 Hancock, H. L.
 Pryor, J.
 Slee, W. E.
 Wauchope, J. A.

TASMANIA

Beaconsfield.—Heathcote, C. F.
 Derby.—Clark, L. C.
 Hobart.—Kennedy, J.
 Launceston.—King, E. M.
 Simson, A.
 Thompson, L. G.
 Moonah.—Williams, L.
 North Lyell.—Coote, C. E.
 Queenstown.—Roberts, R. P.
 Sticht, R.
 Rosebery.—Barker, G.
 South Burnie.—Sale, W. R.
 Waratah.—Millen, J. D.
 Zeehan.—Harris, H.

VICTORIA

Bellarat.—Poole, W.
 Melbourne.—Brown, A. T.
 Courtney, C. F.
 Delprat, G. D.
 Dickenson, F. M.
 Dyson, T. I.
 Greenway, T. J.
 Hartwick, J. S.

Melbourne.—Continued.

Higgins, J. M.
 Hooker, B.
 Kayser, H. W. F.
 Klug, G. C.
 Lempiere, O. T.
 Lewis, J. B.
 Macgeorge, A. J.
 Nicholas, A. M.
 Noyes, H.
 Schlapp, H. H.
 Wilson, H.
 St. Kilda.—Herman, H.
 Kosminsky, I. M.
 Walhalla.—Miller, J.

WESTERN AUSTRALIA

Boulder.—Aarons, J. B.
 Frazer, A.
 Hamilton, R.
 Nicolson, R. B.
 Sutherland, J. W.
 Fimiston.—Black, R. S.
 Caddy, J. P.
 Cleland, E. D.
 McAlulay, D. F.
 Vail, H. E.
 Kalgoorlie.—Moore, B. H.
 Roberts, G. M.
 Varden, R. A.
 Muralgarra Sta.—Wittenoom,
 C. H.
 Perth.—Montgomery, A.
 Shallock, V. F.
 Watkins, A. O.
 Whitfield, H. E.
 Whim Creek.—Sleeman, H. R.

INSTRUCTED TO HOLD
ALL MAIL

Collins, W. J.
 Eiseler, Manuel.
 James, Cyril H.
 Kehler, Charles R.
 Leer, I. Wayne von.
 Mather, Henry A.
 Pearson, William R.
 Wainwright, W. B.

ADDRESS WANTED

Bryce, R. A.
 Disbrow, W. F.
 Kiddie, Thomas.
 Kurie, F. M.
 Marston, P. L.
 Reynolds, Llewellyn.
 Stoddart, A. W.
 Van Ness, William W.
 Watters, Daniel M.

DECEASED

Elected		Died	Elected		Died
1895	*ABBOTT, AI ARTHUR.....	1908	1897	*BENTON, CHARLES W.....	1907
1882	*ABBOTT, ARTHUR V.....	1906	1899	*BEST, JOHN W.....	1904
1905	*ABE, MASAYOSHI.....	1909	1881	*BIDDLE, WILLIAM F.....	1910
1903	*ADAMS, CHARLES C.....	1905	1875	*BIERWITH, L. C.....	1902
1906	**ADAMS, JOHN C.....	1913	1886	*BILD, CARL W.....	1907
1905	*ADAMS, WILLIAM.....	1909	1882	*BILLING, G.....	1890
1903	*ADAMS, W. EDWARD.....	1910	1877	*BILLINGS, GEORGE H.....	1913
1884	*ADDY, MATTHEW.....	1896	1897	*BIRD, ARTHUR H. S.....	1911
1906	*AFFLECK, WILLIAM.....	1911	1897	*BIRD, ROBERT MACDONALD	1913
1889	*AKERS, WILLIAM A.....	1906	1875	*BLACKWELL, EDWARD.....	1880
1905	*ALABASTER, RUPERT C.....	1911	1877	*BLAKE, F. C.....	1891
1899	*ALBERGER, LOUIS R.....	1911	1871	*BLAKE, WILLIAM P.....	1910
1894	*ALLEN, R. B.....	1896	1903	*BLANDY, A. POYNTZ.....	1903
1905	*ALLEN, R. SCOTT.....	1906	1871	*BLANDY, JOHN F.....	1903
1874	*AMLOT, H.....	1892	1897	*BLATCHFORD, JOHN.....	1906
1886	*AMSLER, CARL.....	1894	1871	*BLOSSOM, T. M.....	1876
1898	**ANDERSON, JOHN W.....	1905	1888	*BLUE, JOHN.....	1907
1895	*ANGSTROM, CARL.....	1901	1884	*BOEHMER, MAX.....	1913
1887	*ARCHBALD, JAMES.....	1910	1893	**BOEICKER, RUDOLPH.....	1897
1900	*ARLETT, GEORGE H.....	1906	1882	*BOGGS, WILLIAM R., JR..	1907
1890	*ARMSTRONG, JOHN F.....	1898	1887	*BOIES, HENRY M.....	1903
1882	*ARNOLDS, HUGO.....	1886	1906	*BOND, LOUIS W.....	1908
1875	*ASHBURNER, CHARLES A.....	1889	1886	*BONZANO, ADOLPHUS.....	1913
1872	*ASHBURNER, WILLIAM.....	1887	1892	*BOOTH, EDGAR H.....	1898
1883	*ATKINS, C. M., JR.....	1885	1875	*BORDA, E.....	1897
1875	**ATTWOOD, GEORGE.....	1912	1891	*BOSHER, C. H.....	1894
1905	*AUSTEN, PETER T.....	1907	1871	*BOWDEN, JAMES H.....	1900
1883	**AUSTIN, T. S.....	1906	1886	*BOWMAN, AMOS.....	1894
1897	*AYERS, WILLIAM.....	1898	1886	*BOYLE, THOMAS G.....	1890
1885	*BABCOCK, GEO. H.....	1893	1887	*BRADEN, S.....	1894
1892	*BACHMAN, DAVID I.....	1912	1902	*BRADFORD, WAGER.....	1909
1884	*BAILEY, EDWARD.....	1889	1874	*BRADLEY, GEORGE L.....	1906
1880	*BAILEY, JACKSON.....	1887	1879	*BRAINERD, A. F.....	1893
1910	*BAILIE, ROBERT L.....	1913	1871	*BRAMWELL, J. H.....	1894
1887	*BAKER, THOMAS T.....	1906	1896	*BREISCH, E. E.....	1906
1900	*BALLOU, FRANKLIN.....	1903	1879	*BRIDGMAN, H. L.....	1900
1903	*BAMBERGER, SIDNEY M.....	1911	1881	*BRIGGS, ROBERT.....	1882
1901	†BARBER, WILLIAM B.....	1905	1901	*BRIGGS, ROSWELL E.....	1911
1886	*BARNES, F. W.....	1892	1908	*BRILL, PAUL K.....	1911
1884	†BARNES, GEORGE T.....	1900	1880	*BRINSMADE, J. B.....	1884
1884	*BARR, J. N.....	1904	1895	*BRITTEN, THOMAS J.....	1913
1888	*BARRETT, D. H.....	1888	1887	*BROCK, ARTHUR.....	1909
1877	*BARTLETT, J. C.....	1903	1906	*BROOKS, ROBERT S.....	1909
1890	*BARTLETT, JOHN H.....	1910	1880	*BROWN, A. C.....	1890
1902	*BATCHELOR, WILLIAM T.....	1906	1875	*BROWN, ALEXANDER E.....	1911
1901	*BATTERMAN, C. S.....	1901	1892	*BROWN, AUSTIN H.....	1913
1907	*BAYLES, JAMES C.....	1913	1872	*BROWN, A. J.....	1875
1897	**BEALS, WILLIAM, JR.....	1908	1881	*BROWN, EDWARD L.....	1908
1891	*BECHER, H. M.....	1893	1875	†BROWN, FAYETTE.....	1910
1882	*BEEGER, H.....	1892	1895	*BROWN, HORACE F.....	1906
1888	*BELL, GEORGE A.....	1902	1905	*BROWN, JAMES W.....	1909
1892	*BELL, G. B.....	1893	1895	*BROWN, RAYMOND B.....	1909
1897	**BELL, CHAS. LOWTHIAN.....	1906	1886	*BROWN, T. FORSTER.....	1907
1874	Bell, Sir Lowthian.....	1904	1890	**BROWNE, ARTHUR R.....	1900
1890	*BENNETT, T. A.....	1905	1882	*BROWNING, F. D.....	1885
1889	*BENNETT, DAVID A.....	1897	1885	*BRUCKNER, WILLIAM.....	1887
1892	*BENSUSAN, E. V.....	1906	1890	†BRUNINGS, J. H.....	1893

Elected		Died	Elected		Died
1901	*BRYAN, LUKE W.....	1905	1903	*COLEMAN, R. PREWITT...	1910
1896	*BUCKE, M. A.....	1899	1882	†COLLINGWOOD, FRANCIS..	1911
1902	**BUCKLEY, ERNEST R.....	1912	1895	*COLLINS, ARTHUR L.....	1902
1900	†BUELL, P. A.....	1900	1876	†COLLINS, H. E.....	1896
1882	*BULKLEY, FRED G.....	1908	1881	*CONANT, T. P.....	1891
1879	*BULKLEY, HENRY W.....	1911	1900	*CONNER, JOHN T.....	1908
1874	*BULLOCK, M. C.....	1899	1888	*CONRO, ALBERT.....	1901
1876	*BUNSEN, ROBERT.....	1887	1902	Contreras, Manuel M.....	1902
1876	*BURDEN, JAMES A.....	1906	1882	*CONVERSE, JAMES B.....	1883
1882	*BURLINGAME, E. E.....	1907	1891	*CONYNGHAM, C. M.....	1894
1900	*BURRELL, HENRY.....	1910	1874	*COOK, GEORGE H.....	1886
1896	*BUTLER, CHAUNCEY E.....	1907	1902	*COOM, HENRY.....	1903
1872	†BUTLER, CYRUS.....	1890	1874	*COOPER, EDWARD.....	1905
1900	*BUTLER, W. P.....	1903	1899	†CORBETT, FRANCIS E.....	1901
1893	*BUTTON, EDWARD.....	1900	1871	*CORYELL, MARTIN.....	1892
1886	*BYERS, ALEXANDER M.....	1900	1883	*CORYELL, TORBERT.....	1912
1903	*CADE, EDWIN ARTHUR.....	1903	1903	*COSBY, ROBERT P.....	1910
1876	*CALDWELL, W. B., JR.....	1880	1891	*COWLAND, C. D.....	1894
1901	*CALERO, JOSE.....	1910	1886	*COWLES, E. H.....	1892
1878	*CAMERON, JAMES R.....	1881	1899	†COX, JENNINGS S., JR.....	1913
1899	*CAMPBELL, FRANK J.....	1910	1901	*COX, STERLING B.....	1908
1897	**CAMPBELL, WILLIAM Y.....	1899	1880	*COXE, ALEXANDER B.....	1906
1876	†CANFIELD, A. CASS.....	1904	1871	*COXE, ECKLEY B.....	1895
1893	*CARKEEK, JOHN.....	1900	1874	*COXE, W. E. C.....	1904
1878	*CARNEGIE, THOMAS M.....	1886	1871	*CRAFTS, WALTER.....	1896
1887	*CARPENTER, FRANK R.....	1910	1887	*CRAVEN, FRANK S.....	1889
1891	*CARPENTER, J. H.....	1898	1887	*CRAVEN, HENRY S.....	1889
1897	†CARREL, F. J.....	1894	1879	*CROCKER, GEORGE A.....	1906
1887	*CARROLL, MICHAEL.....	1891	1879	*CROCKER, WILLIAM B.....	1885
1901	*CARROLL, WILLIAM E.....	1904	1906	*CULBERT, MILTON T.....	1911
1893	*CARY, JOHN S.....	1899	1879	*CURRY, HENRY M.....	1900
1903	**CARTER, T. LANE.....	1912	1871	*DADDOW, S. H.....	1875
1878	*CASE, W. H.....	1898	1884	*DAGRON, J. G.....	1895
1892	Castillo, A. del.....	1895	1872	**D'ALIGNY, H. F. Q.....	1875
1873	*CHALFANT, JOHN W.....	1898	1876	*DANIELS, FREDERICK H..	1913
1895	**CHALMERS, JOHN A.....	1912	1883	*DARLEY, E. C.....	1901
1886	*CHAMBERS, R. C.....	1901	1891	†DARLING, J. V.....	1892
1882	*CHANUTE, ARTHUR.....	1895	1891	*DARLING, W. P.....	1896
1879	*CHANUTE, OCTAVE.....	1910	1887	Daubrée, A.....	1896
1879	*CHAPER, MAURICE.....	1896	1905	*DAUGHERTY, EDWIN S..	1905
1882	*CHEEVER, B. W.....	1888	1877	*DAVENPORT, RUSSELL W.	1904
1871	*CHESTER, A. H.....	1903	1891	*DAVEY, GEORGE.....	1908
1890	*CHESTER, EDWARD D.....	1907	1900	*DAVIDOW, ISIDOR.....	1904
1875	*CHISHOLM, HENRY.....	1881	1882	*DAVIDSON, D. R.....	1884
1900	*CHISHOLM, JOHN.....	1912	1899	†DAVIDSON, LOUIS.....	1903
1897	†CHISHOLM, S. S.....	1901	1881	*DAVIES, EDW. S.....	1885
1876	*CHOUTEAU, PIERRE.....	1911	1887	*DAVIES, W. B.....	1891
1897	†CHURCH, MYRON J.....	1912	1886	†DAVIS, M. C.....	1886
1890	*CLARK, C. J.....	1896	1884	†DAYTON, L. M.....	1892
1874	*CLARK, ELLIS.....	1895	1883	*DE CAMP, A. H.....	1895
1877	*CLARK, HENRY G.....	1881	1885	*DE CAMP, EDW. F.....	1895
1887	*CLARK, JOSEPH K.....	1903	1875	*DE CAMP, WILLIAM S.....	1905
1872	*CLARK, R. NEILSON.....	1894	1872	**DE CRANO, E. G.....	1893
1881	*CLARK, WILLIAM.....	1884	1880	*DE PEIGER, R. F. J.....	1883
1886	*CLAUDET, ARTHUR C.....	1913	1881	*DESLOGE, JOHN M.....	1900
1874	*CLAYTON, JOSHUA.....	1889	1903	*DEVINNY, GEORGE V.....	1907
1883	*CLAYTON, W. S.....	1886	1902	*DICKERSON, CLARENCE M	1903
1887	**CLEMENT, VICTOR M.....	1903	1883	*DICKSON, THOMAS.....	1884
1876	*CLEMENS, J. P.....	1876	1897	*DIGGLES, JAMES A.....	1910
1880	**CLIFF, JOHN.....	1912	1902	*DILLON, RALPH.....	1902
1906	*CLIMO, WILLIAM T.....	1908	1884	*DISSTON, HORACE C.....	1902
1890	*CODINGTON, EDMUND W..	1910	1886	*DISSTON, THOMAS S.....	1895
1891	*COGHLAN, F. M.....	1903	1902	*DOBLER, F. C.....	1903
1887	*COBATH, LEMUEL U.....	1908	1884	*DODGE, WALLACE H.....	1895
1896	*COLE, HAROLD M.....	1902	1900	**DODGE, WILLIAM E.....	1903

Elected		Died	Elected		Died
1881	*DODS, JOHN C.	1911	1894	*FULLER, JAMES W.	1910
1892	*DODSON, R. T.	1896	1877	†FULLER, JOHN T.	1885
1897	*DOERR, EDWARD	1904	1898	*FULLER, T. E.	1898
1882	*DOMINICK, F. J.	1895	1891	*FULTON, G. E.	1895
1879	*DORSEY, E. B.	1900	1888	*FURLONGE, W. H.	1896
1887	*DOUGHERTY, CLARENCE E.	1912	1880	*FURMAN, H. VAN F.	1902
1879	*DOYLE, PAT.	1907	1879	*FUSZ, PAUL A.	1910
1907	*DRAKE, FRANCIS V.	1909	1890	*Gaetzschmann, Moritz	1895
1875	†DRESSER, CHARLES A.	1873	1899	**GAGE, ELIPHALET B.	1913
1871	*Drown, Thomas M.	1904	1900	*GALLAGHER, JAMES B.	1908
1900	*DU BOIS, LOUIS C.	1903	1878	*GARDNER, G. CLINTON	1904
1878	*DUDLEY, CHARLES B.	1909	1898	*GARRETSON, OLIVER S.	1908
1889	*DUFFIELD, P. W.	1897	1881	*GARRETT, WILLIAM	1903
1876	*DURFEE, W. F.	1899	1893	*GARRETT, WILLIAM W.	1907
1898	*DWELLE, JESSE E.	1913	1884	†GATEWOOD, R.	1890
1881	*DWIGHT, W. S.	1884	1892	*GIBSON, ROBERT	1906
1888	*EAMES, RICHARD, JR.	1909	1894	*GIBSON, W. K.	1898
1884	*EARLE, FRANK C.	1913	1883	*GILBERT, EDWARD G.	1893
1907	*EATHERLY, ADRIAN D.	1912	1881	*GLENN, WILLIAM	1907
1871	*EGLESTON, THOMAS	1900	1882	*GOETZ, G. W.	1897
1902	*EKMAN, ADOLF	1907	1897	*GOODWILLIE, J. B.	1898
1889	*ELDRIDGE, GEORGE H.	1905	1871	†GOODWIN, H. S.	1892
1903	*ELLIOTT, JOHN S.	1913	1907	*GOROW, BORIS	1913
1879	†ELY, E. B.	1884	1876	*GOULD, ROBERT A.	1878
1891	*ELY, GEORGE H.	1894	1872	†GOWEN, FRANKLIN B.	1889
1881	*EMANUEL, W. H.	1901	1890	*GRACEY, F. P.	1895
1876	*EMERSON, B. F.	1884	1875	†GRAHAM, THOMAS	1892
1880	*EMERY, CHARLES E.	1898	1889	*GRANT, JAMES B.	1911
1877	**EMMONS, SAMUEL F.	1911	1896	*GRANT, JOHN A.	1897
1903	*EMRICH, HORACE H.	1911	1898	*GRAVE, PERCY	1911
1872	*ENGELMANN, HENRY	1899	1908	*GRICE, JOHN M.	1909
1893	†ESCOBAR, MARIO	1901	1877	*GRIDLEY, EDWARD	1887
1898	*EVANS, GEORGE H.	1907	1874	*GRIFFEN, JOHN	1884
1880	*EVANS, JOHN D.	1891	1896	*GRILLO, JULIUS	1911
1887	*EVELETH, J. K.	1907	1887	*GRUBB, CHARLES B.	1911
1887	*FACKENTHAL, JOHN S.	1913	1894	*GRUBB, E. B.	1899
1890	*FARREL, FRANKLIN	1912	1871	*Gruner, L.	1883
1883	*FEGELY, ISAAC	1891	1889	*GUE, T. R.	1907
1881	*FELTON, S. M.	1884	1898	*GUENTHER, ALBERT	1899
1878	*FERGUSON, E. M.	1904	1897	*GUINN, JOHN B.	1905
1876	*FERNEKES, ANTON	1887	1883	*GURLEY, WILLIAM	1887
1886	*FERRIS, G. W. G., JR.	1896	1883	*HADLEY, W. C.	1896
1891	*FERRY, CHARLES H.	1910	1903	**HAGUE, JAMES D.	1908
1886	*FIERO, A. W.	1906	1879	*HAHN, IGNATIUS	1888
1872	*FIRMSTONE, WILLIAM	1875	1888	*HAINSWORTH, WILLIAM	1896
1876	*FISHER, HARVEY	1889	1891	*HALDER, ALBERT H.	1901
1880	*FISHER, H. H.	1888	1891	*HALL, HARRY R.	1911
1897	*FLEMING, JOHN B.	1911	1881	*HALL, JAMES F.	1884
1875	*FOOTE, HERBERT C.	1880	1888	*HALL, JESSE	1902
1882	*FORD, ROBERT G.	1891	1904	*HALLETT, S. I.	1913
1902	**FORRESTER, ROBERT	1910	1894	*HAMILTON, WALKER	1895
1896	*FORSYTHE, ROBERT J.	1908	1889	*HAMMER, HAKON	1896
1903	*FOSTER, CLEMENT LE NEVE	1904	1887	*HANNA, GEORGE B.	1906
1888	*FRANCIS, A. G.	1890	1896	*HANSON, RASMUS	1909
1880	*FRANCIS, GEORGE G.	1907	1895	*HARLOW, MELLE S.	1901
1904	*FRASER, JOHN H.	1906	1900	*HARMON, DANA	1903
1871	**FRAZER, PERSIFOR	1909	1874	*HARNICKELL, A.	1887
1871	*FRAZIER, B. W.	1905	1877	*HARRINGTON, B. F.	1907
1885	*FREELAND, FRANCIS T.	1908	1907	*HARRIS, EDWIN F.	1912
1878	*FREEMAN, H. C.	1900	1897	*HARRIS, FREDERICK S.	1908
1877	†FREEMAN, WILLIAM C.	1903	1872	*HARRIS, STEPHEN	1874
1894	*FRENCH, AARON	1902	1871	*HARRIS, WM. J.	1904
1879	*FRICKE, F. G.	1905	1900	*HART, R. G.	1906
1872	*FRITZ, JOHN	1913	1877	†HART, W. R.	1892
1904	*FULLER, EDWARD L.	1909	1890	*HARTUNG, MAX J.	1894

Elected		Died	Elected		Died
1892	*HARTZELL, H. K.	1911	1871	*HUNT, T. STERRY	1892
1903	*HARVEY, HAROLD H.	1909	1899	†HURLEY, THOMAS J.	1907
1880	†HARVEY, WILLIAM H.	1888	1879	*HUSSEY, C. C.	1884
1903	*HAYARD, FRANCIS T.	1913	1880	*HYNDMAN, E. K.	1884
1894	*HAYDEN, EDWARD S.	1899	1879	*INGERSOLL, S. WARREN	1884
1887	†HAZARD, ROWLAND	1898	1872	†INGHAM, WILLIAM A.	1913
1881	*HEALY, MAURICE	1881	1894	**INGRAM, H. E.	1907
1883	*HEARD, JOHN, JR.	1895	1876	*INMAN, A. L.	1894
1874	*HEARNE, FRANK J.	1907	1890	*IRELAND, THOMAS A.	1902
1904	*HEBERLEIN, MAX	1908	1900	*IRISH, DANA C.	1905
1902	*HECKELMANN, OTTO	1902	1906	*IRVIN, THOMAS A.	1910
1893	*HECKSCHER, RICHARD P.	1903	1872	*IRVING, R. D.	1888
1881	*HEGELER, EDWARD C.	1910	1881	†IRWIN, JOHN H.	1890
1873	*HEINRICH, OSWALD J.	1886	1894	*JACKSON, T. MOORE	1912
1889	*HELMS, ALBERT	1907	1882	*JAMES, ISAAC E.	1887
1875	*HEMPHILL, JAMES	1900	1879	*JAMES, REESE	1899
1900	*HENNE, CHRISTOPHER	1906	1895	*JAMIESON, M. B.	1895
1888	*HENNIN, ALPHONSE	1908	1885	*JANIN, ALEXIS	1897
1886	*HENNING, GUS. C.	1910	1872	**JANIN, HENRY	1911
1892	*HENRY, ADOLPH	1892	1874	*JANNEY, MORRIS P.	1898
1890	*HESSE, CONRAD E.	1910	1901	*JENKINS, THOMAS	1902
1883	*HEWETT, GEORGE C.	1907	1874	*JENNEY, F. B.	1876
1871	*HEWITT, ABRAM S.	1903	1873	*JERNEGAN, J. L.	1881
1890	*HICKS, GEO. J.	1891	1892	*JESSOP, WILLIAM H.	1900
1894	*HILDRETH, R. W.	1895	1898	*JESSUP, ALFRED E.	1907
1888	**HILLARD, CHARLES J.	1907	1904	*JOHNS, THOMAS E.	1907
1889	*HILLMAN, DANIEL	1890	1889	*JOHNSON, GUY R.	1910
1891	*HINTON, F.	1895	1879	*JOHNSON, ISAAC G.	1902
1880	*HOATSON, THOMAS	1897	1880	*JOHNSON, JOSEPH E.	1911
1892	*HOBSON, JOHN B.	1912	1902	*JOHNSON, RALPH I.	1908
1884	*HODGES, A. D., JR.	1910	1898	†JOHNSON, WILLIAM E.	1901
1882	*HODGSON, THOMAS	1896	1899	*JOHNSTON, ALGERNON K.	1909
1888	**HOEFER, EUGENE	1899	1901	†JOHNSTON, W. J.	1907
1876	*HOFFMAN, JOHN W.	1910	1881	*JOHNSTON, W. N.	1886
1890	*HOFIUS, W. D.	1912	1899	*JOLLY, ALEXANDER W.	1906
1884	*HOFMANN, OTTOKAR	1909	1878	*JONES, B. F.	1903
1875	*HOLBROOK, F. N.	1902	1875	*JONES, D. N.	1889
1887	†HOLDEN, E. F.	1899	1887	*JONES, EDWARD	1892
1886	*HOLDEN, L. E.	1913	1881	*JONES, GRIFFITH	1888
1899	*HOLDSWORTH, FRANK A.	1902	1888	*JONES, JAMES F.	1907
1871	*HOLLEY, A. L.	1882	1881	**JONES, WASHINGTON	1911
1887	*HOLLISTER, O. J.	1892	1875	*JONES, W. R.	1889
1875	*HOLLOWAY, J. F.	1896	1888	*JOUSSELINE, A. L.	1897
1903	*HOLMES, EDWIN M.	1911	1906	*KAEDING, HENRY B.	1913
1878	*HOOPER, WILLIAM	1902	1906	*KANE, DANIEL B.	1912
1890	*HOPKE, FRANK E.	1890	1906	**KATSURA, YOICHI	1913
1908	*HORSWILL, FREDERICK A.	1912	1876	*KEELEY, JEROME	1909
1877	*HORTON, N. W.	1886	1900	*KEENER, GEORGE L.	1906
1899	*HOSIE, JAMES P.	1898	1905	*KENNEDY, NEIL	1913
1891	*HOSKING, GEORGE F.	1895	1893	*KENNEDY, ORRAN W.	1913
1894	*HOSKOLD, H. D.	1904	1872	*KENT, JOSEPH C.	1912
1898	*HOWARD, KARL	1907	1888	*KELLY, G. D.	1892
1886	*HOWARD, T.	1896	1890	Keri, BRUD	1905
1886	†HOWE, EPHENETUS	1911	1876	*KERR, W. C.	1885
1895	†HUGHES, CHARLES J., JR.	1911	1872	*KEYES, WINFIELD S.	1906
1886	*HUHN, E. C. O.	1894	1882	*KIMBALL, HIRAM	1899
1881	*HULBERT, THOMAS H.	1889	1907	*KIMBER, ALFRED	1910
1872	*HUMPHREYS, A. W.	1894	1899	**KING, CLARENCE	1901
1882	*HUNGERFORD, WM. S.	1904	1897	†KING, PORTER	1901
1883	*HUNICKE, H. AUGUST	1909	1882	*KING, THOMAS M.	1911
1879	*HUNT, ALFRED E.	1899	1906	*KING, TOM COBB	1908
1891	**HUNT, CHARLES W.	1911	1882	*KINGSLEY, J. COOK	1899
1871	*HUNT, JOSEPH	1897	1909	*KIRK, HARRY E.	1912
1878	*HUNT, JOSHUA	1886	1890	*KNIGHT, FLETCHER H.	1903
1871	*HUNT, THOMAS	1872	1900	*KNIGHT, WILBUR C.	1903

Elected		Died	Elected		Died
1897	*Koch, E. C.	1898	1906	*McComb, Hoyt S.	1907
1891	*Kohler, Walter J.	1901	1903	*McConnell, John	1906
1874	*Koenig, George A.	1913	1874	*McCormack, Henry	1900
1895	*Kornberg, G. A.	1901	1889	*McCrery, Charles	1912
1891	*Krabler, Emil	1909	1897	*McCurdy, John E.	1908
1911	*Kramm, Hugo E.	1913	1885	*McGinnis, J. W.	1891
1891	*Kreischer, C. G.	1891	1877	*McIntire, Henry M.	1880
1884	*Krietz, Henry C.	1890	1880	†McKee, David	1884
1890	*Krimoto, Ren.	1892	1883	*McKeown, S. W.	1898
1893	*Kurtz, Henry M.	1911	1904	*McLaughlin, Harold M.	1912
1896	*Labram, George	1900	1906	*McLaughlin, Wm. L.	1911
1876	*Lamborn, R. H.	1894	1899	*McLean, Gordon	1905
1882	**Landis, Edward K.	1904	1871	*McNair, Thos. S.	1902
1883	*Landesburg, E.	1888	1902	*McNamara, Herbert H.	1905
1893	*Lanning, John G.	1906	1876	*Macintosh, J. B.	1891
1887	*Larnach, W. J. M.	1898	1881	†Mackintosh, W. S.	1884
1883	*Lathrop, William A.	1912	1898	†MacLaren, Duncan	1901
1878	*Laureau, L. G.	1901	1886	*MacLean, F. P.	1891
1892	*Lavalette, E. de	1892	1874	*MacMartin, Archibald	1881
1893	*Lawrence, H. L.	1911	1893	*MacNaughton, James	1905
1895	Le Conte, Joseph	1909	1876	*Macy, Arthur	1891
1897	*Leckie, Robert G.	1913	1894	†Macy, Charles A., 2d.	1901
1899	†Lee, Harry H.	1905	1874	*Maffet, W. R.	1891
1890	*Lee, J. Henry	1911	1905	*Maffett, Robert R.	1912
1876	*Lee, R. H.	1895	1888	*Mahony, Arthur S. J.	1904
1876	*Lee, R. H.	1892	1905	*Mandell, Frank C.	1906
1871	†Lee, Washington	1872	1890	*Mannesmann, Robert	1913
1891	*Lehman, Gustavus W.	1906	1887	*Manness, Charles F.	1887
1882	*Leisenring, E. B.	1894	1878	*Manthey, William	1883
1875	*Leisenring, John	1874	1890	**Manzavino, N.	1899
1891	*Leisenring, Walter	1907	1880	*March, W. J.	1891
1902	*Lengemann, Aug.	1904	1887	*Marsh, Charles W.	1896
1882	*Lennig, Nicholas	1906	1888	*Marsh, Walter	1897
1896	Lesley, J. P.	1903	1881	*Martin, Edward P.	1910
1881	*Lewis, David B.	1887	1879	*Martine, Charles A.	1900
1875	*Lewis, James F.	1901	1878	*Marvin, Selden E.	1899
1871	*Liebenau, Charles von	1875	1897	*Matcham, Charles A.	1911
1887	*Lienau, D. B.	1890	1904	*Mathews, Frederick W.	1907
1905	*Light, Herbert H.	1909	1881	*Mattes, Charles C.	1909
1896	*Linderman, Robert P.	1902	1887	*Matthews, C. W.	1891
1900	*Lindsay, Edward N.	1900	1874	*Maury, M. F.	1886
1902	*Lindsay, William A.	1905	1871	*Maynard, George W.	1913
1889	*Lindsay, William W.	1902	1882	†Means, Archibald	1898
1905	*Livingston, Clermont	1907	1877	*Meister, Herman C.	1911
1891	*Loane, W. E.	1896	1890	*Melliss, David E.	—
1891	*Lobdell, Geo. G.	1894	1899	*Mellors, Paul	1902
1873	*Loiseau, E. F.	1886	1871	*MERCUR, Frederick	1888
1882	*Long, William H.	1906	1900	*MERCUR, Robert S.	1907
1871	†Lord, John C.	1872	1900	*Messer, Edgar H.	1902
1875	*Lord, N. W.	1911	1891	*METCALF, Alfred T.	1910
1882	*Lord, R. F.	1899	1875	*METCALF, William	1909
1874	*Lorenz, W.	1884	1886	*Meyer, A. R.	1905
1881	*Lorenz, W., Jr.	1881	1882	*Michaelis, O. E.	1890
1879	*Lowe, Francis A.	1883	1875	*Mickley, J. W.	1880
1894	*Luckraft, J. S.	1903	1898	*Middleton, W. B.	1899
1903	*Lucy, Frank A.	1909	1877	*Miles, Fred P.	1897
1884	*Lukens, Jawood	1908	1893	*Miller, C. H.	1896
1884	*Luther, R. C.	1905	1895	*Miller, Edmund H.	1906
1888	*McCalley, Henry	1904	1875	*Miller, Reuben	1890
1903	*McCan, E. K.	1910	1904	*Miller, Stephen C.	1908
1879	*McCandless, E. V.	1903	1877	*Mills, James E.	1901
1897	*McCarthy, M. E.	1912	1882	*Moen, Philip W.	1904
1897	*McCartney, Robert J.	1904	1871	*Moffat, E. S.	1893
1871	*McClellan, Arthur	1904	1891	*Moister, I. R.	1896
1898	*McClurg, James A.	1910	1887	*Molson, Charles A.	1907

Elected		Died	Elected		Died
1889	*MOLSON, J. H. R.	1897	1889	*PAUL, HENRY	1904
1877	*MOORE, CHARLES W.	1877	1896	*PEARCE, STANLEY H.	1906
1895	*MOORE, E. W. S.	1895	1894	*PELATAN, LOUIS	1907
1875	*MOORE, JAMES	1901	1885	Percy, John	1889
1874	*MORGAN, CHARLES H.	1911	1882	*PETERS, J. C.	1899
1905	**MORGAN, DONALD R.	1908	1883	*PETERS, SAMUEL	1899
1879	*MORGAN, J.	1892	1902	*PETERSDORFF, C. F. VON	1903
1878	*MORGAN, THOMAS R.	1897	1900	*PETERSON, BERTEL	1909
1879	*MORISON, GEORGE S.	1903	1871	**PETTEE, WILLIAM H.	1904
1895	*MORLEY, B. F.	1903	1888	*PETTIBONE, AUGUSTUS	1890
1875	†MORRIS, ISRAEL W.	1909	1877	*PHELPS, WALTER	1878
1898	**MORRIS, JAMES	1911	1895	*PHILIPS, JOSEPH, JR.	1905
1904	**MORRIS, JOHN F.	1905	1891	*PHILLIPS, A. G.	1903
1874	*MORRIS, S. FISHER	1901	1882	†PHILLIPS, P. E.	1884
1881	*MORSE, H. G.	1903	1882	†PIERSON, O. H.	1882
1899	*MOULDER, H. L.	1903	1881	*PITCAIRN, ROBERT	1909
1896	*MURPHY, THOMAS D.	1911	1872	*PLATT, FRANKLIN	1900
1900	*MUSSEN, HORACE W.	1912	1873	**PLATT, J. C.	1898
1883	*NASON, HENRY B.	1894	1875	*PLATT, W. G.	1885
1879	*NEILSON, JAMES	1893	1872	*PLEASANTS, HENRY	1880
1872	*NEILSON, WILLIAM G.	1906	1880	*PLUMMER, J. W.	1896
1895	*NELSON, W. S.	1897	1902	*POINDEXTER, CHARLES L.	1912
1896	*NESMITH, JOHN W.	1909	1906	*POMEROY, ERNEST Y.	1909
1885	*NEWBERRY, W. E.	1899	1889	*POMEROY, JAMES H.	1903
1871	*NEWTON, HENRY	1877	1900	*POOLE, HERMAN	1906
1874	*NEWTON, ISAAC	1884	1884	*PORTER, GEORGE A.	1892
1873	*NICHOLS, EDW.	1892	1887	Posepny, Franz	1895
1902	*NICHOLS, HARVEY B.	1913	1882	*POTTS, FRANCIS L.	1910
1893	*NICHOLS, N. J.	1896	1886	*POTTS, J. D.	1893
1882	*NICHOLSON, A. H.	1887	1900	*POWELL, JOHN HENRY	1903
1888	**NITZE, H. B. C.	1900	1899	*POWELL, JOHN R.	1902
1881	*NOBLE, SAMUEL	1888	1900	*POWELL, LOUIS W.	1913
1909	*NORBOM, JOHN O.	1911	1886	*PRATT, N. W.	1896
1890	†NORRIE, A. LANFEAR	1910	1885	*PRICE, E. A.	1893
1902	*NORTH, EDMUND D.	1910	1887	*PRICE, J. A.	1892
1906	*NORTH, EDWIN G. N.	1908	1875	†PRIEST, J. R.	1880
1882	*NORTON, F. O.	1893	1881	*PRINCE, F.	1892
1893	*ODLING, F. J.	1906	1891	*PROVIS, RICHARD	1913
1887	*O'FARRELL, JOHN J.	1888	1881	**PULLMAN, J. WESLEY	1912
1871	†OLIVER, PAUL A.	1912	1889	*QUINTARD, E. A.	1903
1888	*OLIVER, WILLIAM	1890	1898	*RAMOS, RICARDO G.	1906
1881	†OOTHOUT, E. A.	1894	1889	*RAMSAY, M.	1892
1897	*ORR, WILLIAM	1905	1876	*RAND, ADDISON C.	1900
1887	*OSGOOD, F. C.	1903	1882	*RAND, JASPER R.	1900
1899	Osmond, Floris	1912	1900	*RAND, JASPER R.	1908
1894	*OWEN, FRANK	1901	1873	**RAND, THEODORE D.	1903
1886	†OWEN, J. R. D.	1887	1870	*RANDOL, JAMES B.	1903
1900	*OWEN, JOSIAH	1909	1913	RANFR, WILLIAM Q.	1914
1882	*PADDOCK, JOHN H.	1903	1907	*RAO, M. N. SRINIVAS	1908
1900	*PAGE, CLARENCE V.	1903	1891	*RAWLING, CHARLES Q.	1902
1873	†PAINTER, A. E. W.	1903	1905	*REDAELLI, PIETRO	1910
1874	*PAINTER, HOWARD	1876	1892	†REDDY, P.	1900
1893	*PAINTER, WILLIAM	1906	1892	*REED, H. L.	1893
1872	*PARK, JAMES, JR.	1883	1900	*REGEL, FERD H.	1910
1887	†PARKER, O. B.	1891	1889	*REID, J. M.	1895
1898	*PARKER, WILLIAM J., JR.	1905	1883	*REINHARDT, H. O.	1894
1875	*PARKIN, CHARLES	1904	1896	†RICH, JACOB M.	1903
1900	*PARKS, JAMES F.	1903	1879	*RICHARDS, ELLEN H.	1911
1875	*PARKS, JOHN C.	1902	1875	*RICHARDS, GEORGE	1900
1874	*PARSONS, CHARLES B.	1910	1884	*RICHARDS, JOHN T.	1896
1874	*PARSONS, CHARLES O.	1894	1905	*RICHARDSON, DAVIS	1909
1883	PATCH, MAURICE B.	1913	1871	*RICHTER, C. E.	1877
1890	Patera, Adolph	1890	1883	Richter, Theodor	1898
1886	*PATTERSON, R. P.	1904	1884	*RICKARD, ALFRED	1896
1888	*PATTERSON, W. E.	1896	1884	*RICKARD, REUBEN	1896

Elected		Died	Elected		Died
1877	†RICKARD, R. H.....	1885	1885	*SIMS, ALFRED W.....	1895
1872	†RICKETSON, JOHN H.....	1900	1902	*SIMS, WM. J.....	1903
1883	*RIDER, W. E.....	1892	1873	*SINGER, WILLIAM.....	1909
1886	*RINGELING, FRANK.....	1893	1893	*SJOTTEDT, ERNST A.....	1912
1898	*RIOSECO, PEDRO P.....	1903	1888	*SKINNER, T. L.....	1894
1883	*RIOTTE, EUGENE N.....	1891	1874	*SLADE, F. J.....	1891
1902	†RIPLEY, CHARLES O.....	1905	1901	*SLAVENS, JOHN H.....	1904
1904	*RISING, ARTHUR F.....	1906	1883	*SLUDER, E. E.....	1897
1899	Roberts-Austen, W. C....	1902	1885	*SMALL, GEORGE W.....	1913
1886	*ROBINSON, GEORGE H....	1906	1880	*SMALLEY, W. A.....	1886
1890	*ROBINSON, L. L.....	1892	1906	*SMART, GEORGE O.....	1911
1878	*ROBINSON, THOMAS W....	1880	1902	*SMIT, EGBERT.....	1908
1904	*ROCK, ALFRED M.....	1907	1890	*SMITH, FREDERICK H....	1899
1903	*ROEPFER, FRANCIS A.....	1908	1877	*SMITH, HAMILTON.....	1900
1882	*ROGERS, A. N.....	1890	1875	*SMITH, H. S.....	1899
1893	*ROOSEVELT, ELLIOTT.....	1894	1894	*SMITH, J. HARCOURT....	1899
1904	*ROSE, GEORGE W.....	1907	1871	*SMITH, T. GUILFORD....	1912
1876	*ROSECRANS, W. S.....	1898	1887	*SMITH, W. T.....	1898
1871	*ROTHWELL, RICHARD P....	1901	1899	*SNEDAKER, J. ANGUS....	1912
1895	*ROTHOFF, WILHELM.....	1897	1904	*SNYDER, BAIRD, JR.....	1913
1900	**SAHLBERG, AUGUST.....	1903	1894	*SPERRY, EDWIN S.....	—
1910	*SAMPSON, ROSWELL E.....	1912	1889	*SPERRY, FRANCIS L.....	1906
1882	*SANTA MARIA, R. DE.....	1883	1900	*SPERRY, JACOB J.....	1905
1886	*SAVAGE, E. G.....	1891	1881	*SPIES, ALBERT.....	1910
1905	*SAYLES, ALBERT W.....	1906	1897	*SPOTSWOOD, GEORGE McL.	1903
1903	*SAYLOR, BENJAMIN F. A....	1911	1889	*SPOTTSWOOD, G. A.....	1896
1882	*SAYLOR, DAVID O.....	1884	1893	*SPROW, J. H.....	1895
1878	**SCAIFE, OLIVER P.....	—	1886	†SQUIER, CHARLES B.....	1904
1909	*SCHADER, HERBERT G.....	1913	1871	*SQUIRE, JOSEPH.....	1911
1907	*SCHAEFER, EDWARD F.....	1908	1889	*STANLEY, HENRY M.....	1902
1892	††SCHAEFFER, CHARLES.....	1903	1900	*STANTIAL, OTIS T.....	1903
1883	*SCHAUFUSS, E. C.....	1889	1877	†STANTON, JOHN.....	1906
1872	*SCHIRMER, I. F. L.....	1877	1897	*STARK, HERBERT S.....	1910
1882	*SCHLEMM, WILLIAM H....	1910	1907	*STEFFENS, CHARLES J....	1908
1891	*SCHLINK, T.....	1893	1872	*STEITZ, AUGUSTUS.....	1876
1886	*SCHMALENSÉE, CARL VON..	1887	1881	*STERLING, HENRY S.....	1882
1883	*SCHMITZ, EMERICH J.....	1905	1901	*STERN, HENRY.....	1908
1902	*SCHNIEWIND, F. W. C....	1913	1881	*STEFELDT, C. A.....	1896
1882	*SCHUCHARD, CHARLES.....	1883	1894	*STEVENS, ANDREW.....	1895
1876	†SCHWARTZ, J. E.....	1900	1899	*STEVENS, EDWIN A.....	1902
1880	*SCOTT, CYRUS E.....	1912	1905	*STEVENS, HORACE J.....	1912
1871	*SCRANTON, W. H.....	1889	1896	*STEVENS, WM. F.....	1902
1901	**SEALE, HERBERT P.....	1908	1885	*STICHT, ERNEST.....	1911
1905	*SEATON, WILLIAM, JR....	1908	1891	*STICKNEY, C. WADE.....	1904
1888	*SEDDON, RICHARD J.....	1906	1881	*STINSON, JOHN M.....	1884
1888	*SEDDON, T.....	1896	1906	*STIRLING, JAMES.....	1909
1900	†SEEGER, LUDWIG.....	1905	1874	*ST. JOHN, I. M.....	1880
1890	Serlo, Albert.....	1898	1885	*STOCKWELL, N. S.....	1888
1904	*SEVIER, IRVING H.....	1904	1891	*STODDARD, A. B.....	1900
1906	*SEVIER, JOHN C.....	1909	1886	*STODDER, R. H.....	1889
1893	*SEYMOUR, L. I.....	1900	1872	*STOEHLING, HERMANN...	1875
1905	*SHALER, FRED J.....	1908	**STOBER, EDWARD G.....		1906
1877	*SHEAFER, P. W.....	1891	1902	*STOBER, GUSTAVUS H....	1905
1909	*SHELBY, CHARLES F.....	1911	1890	*STOLLMEYER, A. B.....	1890
1875	*SHERRERD, ALEXANDER H..	1913	1884	*STONE, CHARLES P.....	1887
1888	**SHIELDS, C. O.....	1896	1892	*STONE, G. G.....	1893
1875	*SHINN, W. P.....	1892	1906	*STOREY, THOMAS W. P....	1907
1899	*SHIPMAN, H. A.....	1910	1888	*STRAKER, TOOKE.....	1892
1901	*SHROM, HARRY L.....	1907	1893	*STRIEDINGER, J. H.....	1894
1881	*SICKLES, T. E.....	1885	1905	*STUDY, W. L.....	1905
1879	Siemens, C. William.....	1883	1887	*SUTCLIFFE, JOHN.....	1910
1872	*SILLIMAN B.....	1885	1899	**SUTHERLAND, W. J.....	1911
1871	*SILLIMAN, J. M.....	1896	1904	*SWAN, ARCHIBALD A.....	1911
1902	*SIMPSON, GILBERT C.....	1907	1900	*SWAN, ROBERT M. W....	1905
1887	*SIMPSON, JAMES C.....	1906	1903	*SWANEY, HOMER H.....	1904

Elected		Died	Elected		Died
1899	*SWEET, THOMAS G.....	1912	1886	*WALKER, W. J. B.....	1894
1879	*SWINDELL, WILLIAM.....	1902	1897	*WALLACE, JAMES P.....	1910
1898	*SWOYER, JOHN H.....	1899	1874	*WALSH, EDWARD, JR.....	1901
1873	*SYMINGTON, W. N.....	1899	1900	**WALSH, THOMAS F.....	1910
1871	*SYMONE, W. R.....	1888	1884	*WALTER, T. FRANK.....	1888
1889	*SZONTAGH, OSCAR.....	1903	1872	*WALE, ISIDOR.....	1877
1900	*TAUNTON, F. W.....	1900	1902	*WANLESS, GEORGE J.....	1912
1892	*TAYLOR, GEORGE R.....	1903	1878	†WARNER, L. E.....	1884
1881	**TAYLOR, PERCYVALE.....	1912	1875	**WARTENWEILER, ALFRED.....	1912
1875	*TAYLOR, W. J.....	1903	1882	*WATERS, J. H. E.....	1893
1875	*TEFFT, WALTER.....	1885	1886	*WATERS, THOMAS J.....	1898
1886	*TERHUNE, RICHARD H.....	1905	1887	*WATSON, FREDERICK M.....	1900
1882	*THAW, WM., JR.....	1892	1890	*WATSON, RALPH W.....	1907
1891	*THIELEN, ALEXANDER.....	1897	1897	*WATSON, WM.....	1902
1900	**THIES, ERNST A.....	1908	1881	*WATTS, D.....	1893
1892	*THIERY, JOSEPH.....	1905	1911	†WEAVER, HENRY M.....	1912
1871	*THOMAS, DAVID.....	1882	1882	*WEBB, H. WALTER.....	1900
1892	†THOMAS, D. M.....	1895	1885	Wedding, Hermann.....	1908
1871	*THOMAS, JOHN.....	1897	1875	*WEEKS, JOSEPH D.....	1896
1871	*THOMAS, SAMUEL.....	1906	1895	*WEIR, ROBERT S.....	1898
1881	*THOMAS, SIDNEY G.....	1885	1909	*WEISS, ROBERT A.....	1911
1875	*THOMPSON, C. O.....	1885	1875	*WELCH, ASHBEL.....	1882
1894	**THOMPSON, F. A.....	1897	1890	*WELLMAN, CHARLES H.....	1905
1876	*THOMPSON, HEBER S.....	1911	1880	*WELLS, BARD.....	1893
1896	†THOMPSON, WILLIAM T.....	1899	1875	*WENDEL, A.....	1881
1893	*THOMSON, JOHN L.....	1900	1874	*WENDT, A. F.....	1893
1879	*THONARD, LEON.....	1886	1886	*WESTINGHOUSE, GEORGE.....	1914
1902	*THOW, SYDNEY.....	1907	1888	*WEST, A. R.....	1893
1875	*THURSTON, ROBERT H.....	1908	1896	**WETHERILL, JOHN P.....	1906
1881	*TILEMAN, JOHN N.....	1888	1875	*WHEATLEY, CHARLES M.....	1882
1903	*TISDALE, JOHN N.....	1905	1875	*WHEELER, MOSES D.....	1889
1902	*TOD, HERBERT N.....	1908	1892	*WHEELER, S. BOWMAN.....	1909
1900	*TOLL, ABEL H.....	1906	1907	*WHEELER, WILFRED F.....	1909
1876	*TORRANCE, J. F.....	1895	1882	*WHEELOCK, JEROME.....	1902
1890	*TORREY, GRAY.....	1898	1900	*WILLARD, EUGENE B.....	1907
1897	*TOTTEN, ALFRED I.....	1905	1896	*WILLIAMSON, WILLIAM D.....	1912
1891	*TOUZEAU, EDWARD M.....	1911	1879	†WHILDIN, W. I.....	1882
1878	*TOWEE, A.....	1891	1892	*WHITAKER, THOMAS D.....	1896
1879	*TOWNSEND, HENRY T.....	1907	1886	*WHITE, JAMES B.....	1887
1893	*TREADWELL, EDWIN D.....	1913	1886	*WHITE, MAUNSEL.....	1912
1887	*TRIMBLE, A. J.....	1913	1890	*WHITEHEAD, CABELL.....	1908
1883	*TRIPPEL, ALEXANDER.....	1896	1898	*WHYTE, JOHN S.....	1902
1881	*TROILIUS, M.....	1886	1877	*WIESTLING, G. B.....	1891
1897	*TUCKER, CHARLES R. L.....	1902	1885	*WILCOX, S.....	1893
1871	Turner, Peter Ritter v.....	1897	1883	*WILKES, JOHN.....	1909
1895	*TURNER, ROBERT B.....	1903	1900	**WILKINSON, ARTHUR.....	—
1877	*TUTTLE, H. A.....	1888	1903	*WILLIAMS, DELOS V. A.....	1908
1886	*TYSON, JAMES W.....	1900	1888	*WILLIAMS, FRANK.....	1901
1890	*ULRICH, GEORGE H. F.....	1900	1899	**WILLIAMS, FREDERICK DE L.....	1909
1899	*VALE, STEPHEN W.....	1902	1903	*WILLIAMS, HARVEY L.....	1905
1876	*VALENTINE, M. D.....	1911	1875	*WILLIAMS, HENRY.....	1902
1884	*VAN SLOOTEN, WM.....	1901	1883	*WILLIAMS, J. FRANCIS.....	1891
1887	*VAN TUYLL, C. B.....	1890	1883	*WILLIAMS, J. J.....	1892
1888	*VAN WICKLE, A. S.....	1898	1883	*WILLIAMS, LEWIS.....	1907
1889	*VAN ZANDT, F.....	1892	1887	*WILLIAMS, OLIVER.....	1904
1905	††VARICLÉ, JEAN A.....	1907	1876	*WILSON, J. A.....	1896
1880	*VEEDER, H.....	1896	1887	*WILSON, J. W.....	1894
1874	*VEZIN, HENRY A.....	1902	1900	**WILSON, RICHARD.....	1913
1902	*VIRGOE, WALTER H.....	1905	1886	*WILSON, WALTER B.....	1904
1891	*WAGNER, J. R.....	1899	1898	*WISTER, JOHN.....	1900
1904	*WAINWRIGHT, J. H.....	1911	1871	†WITHERBEE, J. G.....	1875
1888	*WAITHMAN, HUBERT.....	1891	1871	**WITHERBEE, THOMAS F.....	1909
1894	*WALKER, HAMILTON.....	1895	1882	*WOOD, ALVINUS B.....	1910
1878	†WALKER, JOHN A.....	1907	1883	*WOOD, HOWARD.....	1911
1885	†WALKER, JOSEPH R.....	1901			

DECEASED

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Elected		Died	Elected		Died
1893	*WOOD, JAMES G.....	1899	1876	*WRIGLEY, H. E.....	1884
1883	†WOOD, W. DEWEES.....	1899	1901	*WRINKLE, L. F. G.....	1902
1881	*WOOD, WM. J.....	1885	1900	*WUENSCH, ALFRED F.....	1910
1904	*WOODBURY, FREDERICK E.	1914	1881	*WURTS, C. P.....	1892
1895	*WOODFORD, CLARENCE A.	1898	1883	*YARDLEY, THOMAS W....	1900
1879	*WORTHINGTON, H. R.....	1880	1895	*YEATES, WILLIAM S.....	1908
1900	*WRIGHT, CARY.....	1908	1879	**YOUNG, JAMES B.....	1906
1880	*WRIGHT, CHARLES E.....	1888	1891	*YOUNG, JAMES W. R.....	1902
1902	*WRIGHT, FRED A.....	1903	1894	*YOUNG, JOHN W.....	1912
1871	†WRIGHT, HARRISON.....	1885			

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1. Any society of undergraduates at a technical school, comprising students in any branch of engineering, metallurgy, chemistry, geology, etc., may be recognized by the Board of Directors in its discretion as an Affiliated Student Society, and its name, together with the names of its President and its Secretary, may be published in the *Bulletin* or the *Year Book* of the Institute. The individual members of such a society will not be catalogued as individual members or associates of the Institute, but may at any time be proposed for election as members or associates of the Institute, in the usual way.

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4. Upon the order of the Secretary or other designated officer of any such society, accompanied with the necessary remittance, the specified number of copies of the *Bulletin* for one year will be sent postpaid to him at the reduced price (now \$5 per annum) given to public libraries. Supplementary orders at the same price will be filled as long as the supply on hand permits. The volumes of *Transactions* will be similarly furnished at the price charged to members of the Institute for extra copies (now \$6 per volume). (The *Bulletin*, issued monthly, contains all the technical and professional papers published in the *Transactions*, and in addition much information concerning the library and other Society matters; but it is not finally revised and indexed.)

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University of Wisconsin, Madison	Mining Club	R. J. Stengl	M. C. Lake.
Lehigh University, So. Bethlehem, Pa.	Mining and Geological Society	Robert C. Mickel	Edward B. Snyder.
University of Minnesota, Minneapolis	School of Mines Society	C. A. Walker	A. C. Bierman.
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University of Idaho, Moscow	Associated Miners	Walter P. Scott	Bert F. Smith.
State College of Washington, Pullman	Mining and Geological Society	John F. Foran	Thomas C. Puckett.
University of Texas, Austin	Texas Technical Society, School of Mines	G. C. Cartwright	David S. Alley.
Ohio State University, Columbus	Student Branch of the A. I. M. E.	Hugh B. Lee	E. P. Elliott.
Stanford University, Stanford Univ., Cal.	Stanford Geology and Mining Society	B. E. Parsons	E. D. Nolan.
Columbia University, New York, N. Y.	Senior Mining Society		
University of California, Berkeley	Mining Association	D. M. Drumheller, Jr.	J. B. Orynski.
Tufts College, Tufts College, Mass.	Chemical Society	F. D. Whittemore	E. W. Hays.
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Case School of Applied Science, Cleveland, O.	Pick and Shovel Club	M. T. Whelan	Lloyd A. Collier.
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Pennsylvania State College, State College	Mining Society	Ralph E. Kirk	Willard M. Lindsey

LIST OF THE MEETINGS OF THE INSTITUTE AND THEIR LOCALITIES FROM ITS ORGANIZATION TO MARCH, 1914

Trans.					Trans.				
No.	Place	Date	Vol.	Page	No.	Place	Date	Vol.	Page
1.	Wilkes-Barre, Pa.*	May, '71.	1	3	55.	Ottawa, Canada	Oct., '89.	18	xxiv.
2.	Bethlehem, Pa.	Aug., '71.	1	10	56.	Washington, D. C.*	Feb., '90.	18	xxx.
3.	Troy, N. Y.	Nov., '71.	1	13	57.	New York, N. Y.	Sept., '90.	19	vii.
4.	Philadelphia, Pa.	Feb., '72.	1	17	58.	New York, N. Y.*	Feb., '91.	19	xrv.
5.	New York, N. Y.*	May, '72.	1	20	59.	Cleveland, O.	June, '91.	20	xvi.
6.	Pittsburg, Pa.	Oct., '72.	1	25	60.	Glen Summit, Pa.	Oct., '91.	20	lxi.
7.	Boston, Mass.	Feb., '73.	1	28	61.	Baltimore, Md.*	Feb., '92.	21	xix.
8.	Philadelphia, Pa.*	May, '73.	2	3	62.	Plattsburg, N. Y.	June, '92.	21	xxxiii.
9.	Easton, Pa.	Oct., '73.	2	7	63.	Reading, Pa.	Oct., '92.	21	xliv.
10.	New York, N. Y.	Feb., '74.	2	11	64.	Montreal, Canada*	Feb., '93.	21	hi.
11.	St. Louis, Mo.*	May, '74.	3	3	65.	Chicago, Ill.	Aug., '93.	22	xxii.
12.	Hasleton, Pa.	Oct., '74.	3	8	66.	Virginia Beach, Va.*	Feb., '94.	24	xvii.
13.	New Haven, Conn.	Feb., '75.	3	15	67.	Bridgeport, Conn.	Oct., '94.	24	xxxv.
14.	Dover, N. J.*	May, '75.	4	3	68.	Florida†	Mar., '95.	25	xix.
15.	Cleveland, O.	Oct., '75.	4	9	69.	Atlanta, Ga.	Oct., '95.	25	xxxiii.
16.	Washington, D. C.	Feb., '76.	4	18	70.	Pittsburg, Pa.*	Feb., '96.	26	xvii.
17.	Philadelphia, Pa.†	June, '76.	5	3	71.	Colorado.	Sept., '96.	26	xxix.
18.	Philadelphia, Pa.	Oct., '76.	5	19	72.	Chicago, Ill.	Feb., '97.	27	xvii.
19.	New York, N. Y.	Feb., '77.	5	27	73.	Lake Superior	July, '97.	27	xxx.
20.	Wilkes-Barre, Pa.*	May, '77.	6	3	74.	Atlantic City, N. J.*	Feb., '98.	28	xvii.
21.	Amenia, N. Y.	Oct., '77.	6	10	75.	Buffalo, N. Y.	Oct., '98.	28	xxvii.
22.	Philadelphia, Pa.	Feb., '78.	6	18	76.	New York, N. Y.*	Feb., '99.	29	xvii.
23.	Chattanooga, Tenn.*	May, '78.	7	3	77.	California.	Sept., '99.	29	xliz.
24.	Lake George, N. Y.	Oct., '78.	7	103	78.	Washington, D. C.*	Feb., '00.	30	xix.
25.	Baltimore, Md.*	Feb., '79.	7	217	79.	Canada.	Aug., '00.	30	xlv.
26.	Pittsburg, Pa.	May, '79.	8	3	80.	Richmond, Va.*	Feb., '01.	31	xix.
27.	Montreal, Canada.	Sept., '79.	8	121	81.	Mexico.	Nov., '01.	32	cxviii.
28.	New York, N. Y.*	Feb., '80.	8	275	82.	Philadelphia, Pa.†	May, '02.	33	xxxv.
29.	Lake Superior, Mich.	Aug., '80.	9	1	83.	New Haven, Conn.	Oct., '02.	33	xlvii.
30.	Philadelphia, Pa.*	Feb., '81.	9	275	84.	Albany, N. Y.*	Feb., '03.	34	xxiii.
31.	Staunton, Va.	May, '81.	10	1	85.	New York, N. Y.	Oct., '03.	34	lxi.
32.	Harrisburg, Pa.	Oct., '81.	10	119	86.	Atlantic City, N. J.*	Feb., '04.	35	xxiii.
33.	Washington, D. C.*	Feb., '82.	10	225	87.	Lake Superior	Sept., '04.	35	xlii.
34.	Denver, Colo.	Aug., '82.	11	1	88.	Washington, D. C.	May, '05.	36	xlii.
35.	Boston, Mass.*	Feb., '83.	11	217	89.	British Columbia	July, '05.	36	liii.
36.	Roanoke, Va.	June, '83.	12	3	90.	Bethlehem, Pa.	Feb., '06.	37	xli.
37.	Troy, N. Y.	Oct., '83.	12	175	91.	London, England.	July, '06.	37	xlviii.
38.	Cincinnati, O.*	Feb., '84.	12	447	92.	New York, N. Y.	April, '07.	38	li.
39.	Chicago, Ill.	May, '84.	13	1	93.	Toronto, Canada.	July, '07.	38	lii.
40.	Philadelphia, Pa.	Sept., '84.	13	285	94.	New York, N. Y.	Feb., '08.	39	xli.
41.	New York, N. Y.*	Feb., '85.	13	585	95.	Chattanooga, Tenn.	Oct., '08.	39	xlviii.
42.	Chattanooga, Tenn.	May, '85.	14	1	96.	New Haven, Conn.	Feb., '09.	40	xlii.
43.	Halifax, N. S.	Sept., '85.	14	307	97.	Spokane, Wash.	Sept., '09.	40	xlviii.
44.	Pittsburg, Pa.*	Feb., '86.	14	587	98.	Pittsburg, Pa.	Mar., '10.	41	xxviii.
45.	Bethlehem, Pa.	May, '86.	15	lxiii.	99.	Canal Zone.	Nov., '10.	41	xlv.
46.	St. Louis, Mo.	Oct., '86.	15	lxx.	100.	Wilkes-Barre, Pa.	June, '11.	42	xxxiv.
47.	Scranton, Pa.*	Feb., '87.	15	lxxvii.	101.	San Francisco, Cal.	Oct., '11.	42	xliv.
48.	Utah and Montana	July, '87.	16	xvii.	102.	New York, N. Y.	Feb., '12.	43	lxxvii.
49.	Duluth, Minn.	July, '87.	16	xxiv.	103.	Cleveland, Ohio.	Oct., '12.	44	vii.
50.	Boston, Mass.*	Feb., '88.	16	xxviii.	104.	New York, N. Y.	Feb., '13.	45	xv.
51.	Birmingham, Ala.	May, '88.	17	xix.	105.	Butte, Mont.	Aug., '13.	46	
52.	Buffalo, N. Y.	Oct., '88.	17	xxiv.	106.	New York, N. Y.	Oct., '13.	47	
53.	New York, N. Y.*	Feb., '89.	17	xxi.	107.	New York, N. Y.	Feb., '14.	48	
54.	Colorado.	June, '89.	18	xvii.					

*Annual meeting for the election of officers. The rules were amended at the Chattanooga meeting, May, 1878, changing the annual election from May to February.

†Begun in May at Easton, Pa., for the election of officers, and adjourned to Philadelphia.

‡Begun in February at New York City, for the election of officers, and adjourned to Florida.

§Begun in February at New York City, for the election of officers, and adjourned to Philadelphia.

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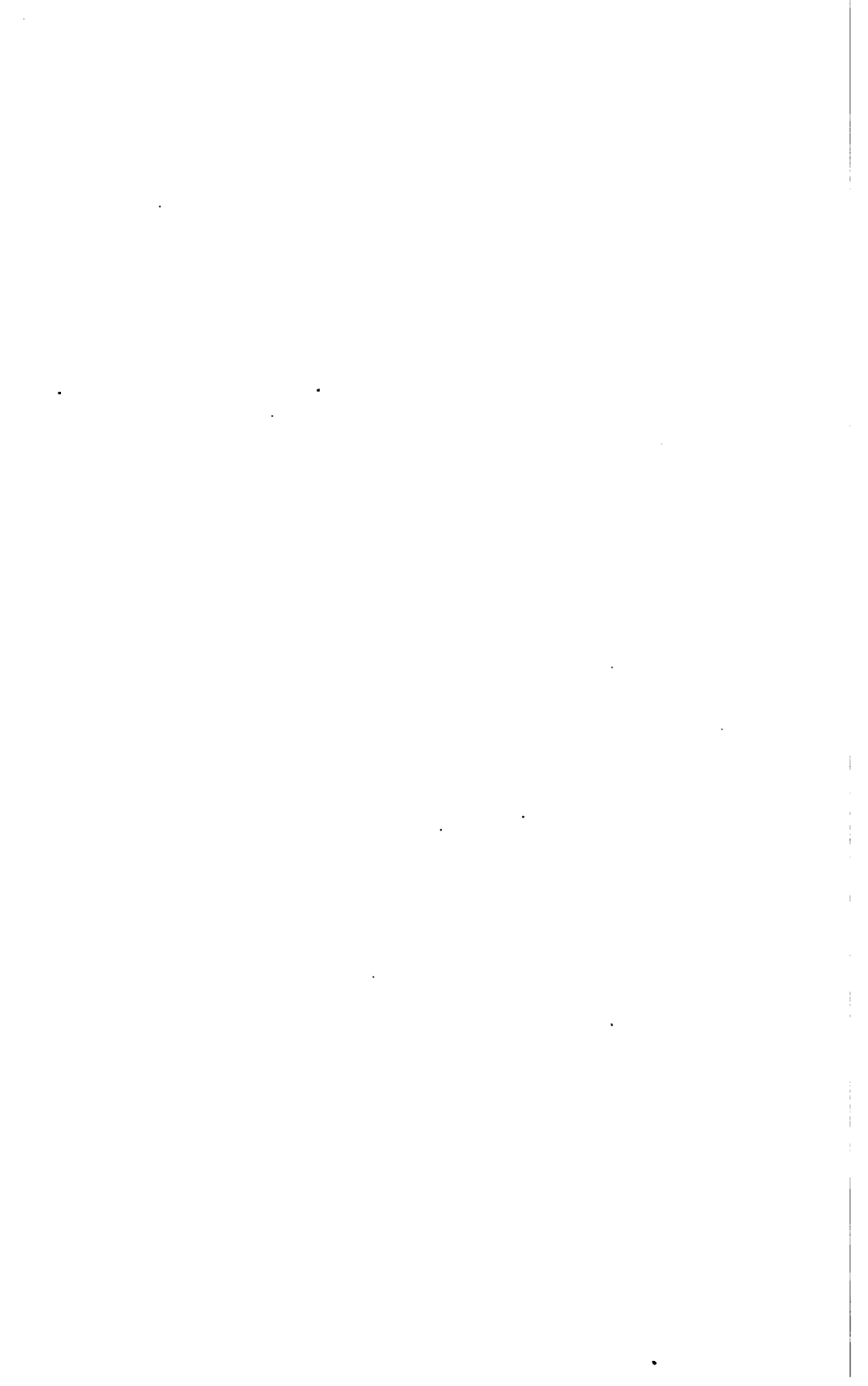
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Extra copies of pamphlets, if ordered before the printing of the *Bulletin*, will be furnished to members of the Institute at special rates.



CERTIFICATE OF INCORPORATION.

[AMENDED NOV. 22, 1912.]

WE the undersigned, being all persons of full age and citizens of the United States, and a majority residents of the State of New York, desiring to form a corporation pursuant to the provisions of the Membership Corporations Law for the purpose of incorporating, as provided in Section 5 of Article I. of said law, the existing unincorporated association known as American Institute of Mining Engineers, do hereby make, acknowledge and file this Certificate for that purpose, and do Certify as follows:

I. That the American Institute of Mining Engineers is an unincorporated association organized and existing with the object of promoting the arts and sciences connected with the economic production of the useful minerals and metals and the welfare of those employed in these industries by means of meetings for social intercourse and the reading and discussion of professional papers, and to circulate by means of publications among its members and associates the information thus obtained.

II. That the persons duly appointed or designated to manage the affairs of said association are designated by the rules thereof Members of its Council; that the undersigned are all members of said Council as the same was constituted on the 29th day of December, 1904.

III. That on said last-mentioned date a regularly called meeting of said association was held at its office in the Borough of Manhattan, City of New York; that thirty days before such meeting notice of the intention to incorporate said association was given by mail to each member thereof whose residence or post-office address is known; that at said meeting the following resolutions were offered, seconded and duly adopted by the unanimous vote of all its members then present, to wit:

"Resolved, That it is the sense of the members and associates of the American Institute of Mining Engineers in general meeting assembled that it is desirable and necessary for the well being of said association and its members and for the furtherance of the objects for which the same has been formed, that said association incorporate under the Membership Corporations Law of the State of New York;

"And Further Resolved, That the Members of the Council of this Association, or a majority thereof, be and they hereby are authorized, in accordance with the provisions of Section 5 of Article I. of the Membership Corporations Law, to incorporate this association for the same purposes for which it has been organized and conducted, in the manner provided in Article II. of said law;

"And Further Resolved, That the name of said corporation as hereby adopted by this meeting shall be American Institute of Mining Engineers.

"And Further Resolved, That the said incorporators shall be named in the Certificate of Incorporation as directors of such corporation until its first annual meeting, and that such directors and their successors in office shall be and they hereby are authorized to enact and adopt a Constitution and By-Laws for the government of said corporation."

IV. That the name of the proposed corporation is American Institute of Mining Engineers.

V. That the purposes for which this corporation is to be formed are: To promote the arts and sciences connected with the economic production of the useful minerals and metals and the welfare of those employed in these industries by means of meetings for social intercourse, and the reading and discussion of pro-

essional papers, and to circulate by means of publications among its members the information thus obtained; and to establish and maintain a place of meeting for its members and a hall for the reading of papers and delivery of addresses, and a library of books relating to subjects cognate to the sciences and arts of mining and metallurgy.

VI. That the territory in which the operations of this corporation are to be principally conducted is the United States of America, and the principal office for the transaction of its affairs is to be located in the City, County and State of New York.

VII. That the duration of this corporation is to be perpetual.

VIII. That the number of Directors of this corporation is to be twenty-four, consisting of one President, two Past Presidents, six Vice-Presidents, and fifteen other Directors; that at the annual meeting to be held in February, 1913, there shall be elected to serve, jointly with the six members of the former Board whose terms will not then have expired, one President, who shall serve as such for one year, and as Past President for two years; two Past Presidents to be selected from former Presidents of the Institute, one to serve for one year and one to serve for two years; six Vice-Presidents, of whom two shall be elected to serve for one year, two for two years and two for three years, and nine Directors, of whom two shall be elected to serve for one year, two for two years and five for three years.

After the year 1913 there shall be elected at each annual meeting one President to serve as such for one year and as Past President for two years; two Vice-Presidents to serve for three years and five Directors to serve for three years.

At each subsequent annual meeting so many Directors only shall be elected as shall be necessary to fill vacancies then existing in the Board, and each Director then chosen shall be elected to serve for three years unless the vacancy which he shall be chosen to fill has been caused otherwise than by expiration of the former incumbent's term of office, in which event he shall be elected to serve for the balance of his predecessor's unexpired term.

IX. That the time for holding the annual meeting of this corporation shall be the third Tuesday of February in each year.

X. That the names and post-office addresses of the subscribers hereto who are to be directors of this corporation until the first annual meeting are

Names.	Post-Office Addresses.
James Gayley,	71 Broadway, New York City;
Frank Lyman,	88 Wall Street, New York City;
James F. Kemp,	Columbia University, New York City;
Charles H. Snow,	New York University, New York City;
Frank Klepetko,	24 State Street, New York City;
Thomas A. Rickard,	261 Broadway, New York City;
James Douglas,	99 John Street, New York City;
Albert R. Ledoux,	99 John Street, New York City;
Rossiter W. Raymond,	99 John Street, New York City.

The above certificate, dated December 30, 1904, was signed and acknowledged by the subscribers before William A. Lockwood, Notary Public (No. 74), New York County.

I, the undersigned, Justice of the Supreme Court of the State of New York, do hereby approve of the above Certificate of Incorporation of the American Institute of Mining Engineers, and do authorize the same to be filed.

SAMUEL GREENBAUM,
Justice of the Supreme Court.

January 7, 1905.

CONSTITUTION. .

[ADOPTED FEB. 18, 1913.]

ARTICLE I.

NAME AND OBJECT.

SEC. 1. This Institute is incorporated under the Membership Corporations law of the State of New York; its corporate name is American Institute of Mining Engineers; and its objects are such as are stated in its Certificate of Incorporation.

ARTICLE II.

MEMBERS.

SEC. 1. The membership of the Institute shall comprise four classes, namely: 1. Members; 2. Honorary Members; 3. Associates; 4. Junior Members.

All members shall be equally entitled to the privileges of membership, excepting that Honorary Members, Junior Members, and Members and Associates whose residences shall be outside of the United States, Mexico, and Canada shall not be entitled to vote. Members and Associates residing within the United States of America, Mexico, and Canada, and not in arrears for dues, shall be entitled to vote in person at the meetings of the Institute, or, as hereinafter provided for, by letter ballot.

SEC. 2. The following classes of persons shall be eligible for membership in the Institute, namely: as Members, all professional mining engineers, geologists, metallurgists, or chemists, and all persons actively engaged in mining and metallurgical engineering, geology, or chemistry; as Associates, all persons desirous of being connected with the Institute who in the opinion of the Board of Directors are suitable.

As Junior Members, all students in good standing in engineering schools who have not taken their degrees and who are nominated by at least two of their instructors. A Junior Member may remain such not longer than three years after leaving the engineering school, at the end of which period his qualifications to become a Member or Associate must be passed upon by the Membership Committee. If elected he shall pay at that time the entrance fee and dues of a Member or Associate.

Every candidate for election as a Member, Associate, or Junior Member must be proposed for election by at least three Members or Associates, must be approved by the Committee on Membership, as prescribed in the By-Laws, and must be elected by the Board of Directors.

SEC. 3. Not less than three-fourths of the votes cast shall be necessary to an election; newly elected candidates shall be immediately notified of their election and also of their obligations, by the Secretary of the Institute. Every person so elected shall become a Member or Associate or Junior Member of the Institute in

the class to which he is chosen, upon payment of his initiation fee, if required by this Constitution, and first year's dues, as hereinafter stated. Each candidate for Honorary Membership must be recommended by at least ten Members and must be elected by ballot at a meeting of the Board of Directors by the unanimous vote of the Directors present; provided, however, that the number of Honorary Members shall at no time exceed twenty.

SEC. 4. If any person elected a Member, Associate, or Junior Member does not within four months after the mailing of notice of his election accept the same and pay his initiation fee, if required, and dues for the year in which he was elected, his election shall be null and void and he shall be notified thereof by the Secretary of the Institute; providing, however, that if elected in the months of October, November, or December, the candidate may, at his option, pay dues only for the ensuing year, in which case he shall be entitled to receive the *Bulletin* of the Institute for the months of November and December, but not the annual volume of the year during which he was elected to membership.

SEC. 5. The Board may at any time, for good and sufficient reasons, change the classification of a member of any class except Honorary Members.

ARTICLE III.

DUES.

SEC. 1. The dues of Members and Associates shall be, until otherwise determined by the Institute, ten dollars per annum, and those of Junior Members shall be five dollars per annum. All dues shall be payable in advance on the first day of each calendar year, and notice to this effect shall be published in the last number of the *Bulletin* of each calendar year, and a bill shall be mailed to each Member, Associate, and Junior Member on the first day of the month of January in each year, stating the amount of dues and date when payable and the penalty and conditions incident to default in payment within the limit of time set by the Constitution.

Each newly elected Member or Associate shall pay, immediately on notification of his election, an initiation fee of ten dollars; Junior Members shall not pay any initiation fee. Honorary Members shall not be liable for initiation fees or dues.

If any Member, Junior Member, or Associate is in arrears for four months, the *Bulletin* shall no longer be sent to him and he shall be notified by the Secretary of the Institute that no publications will be sent him until his arrears be paid. Any Member, Junior Member, or Associate in arrears for one year shall be dropped from the rolls unless the time for payment is extended by the Directors. A member so dropped may be reinstated by the Directors on paying all arrears of dues.

SEC. 2. The Board of Directors shall have the right to increase the dues of the membership for the next ensuing year or years by any sum not to exceed the amount of five dollars per annum, such increase of dues to be applicable solely to the extinction of the principal of the land debt of the Institute. As soon as such indebtedness is paid the dues shall automatically return to those provided in Section 1 of this Article.

SEC. 3. Any Member or Associate not in arrears may become, by the payment of one hundred and fifty dollars at one time, a Life Member or Life Associate, and shall not be liable thereafter to pay annual dues. The money thus received shall be invested and only the income thereof used for current expenses of the Institute.

ARTICLE IV.

BUSINESS MEETINGS OF THE INSTITUTE.

SEC. 1. The annual meeting of the Institute for the election of Directors and transaction of other business shall be held at the headquarters of the Institute in the City of New York on the third Tuesday in February in each year. A report of the financial condition of the Institute and an abstract of the accounts shall be furnished by the Directors, and presented at each annual meeting.

SEC. 2. Special business meetings of the Institute may be held at such times and places in the State of New York as the Board of Directors may appoint, upon notice to all Members and Associates entitled to vote, directed to each at his last known post-office address, and mailed not less than twenty days before the date fixed for such meeting.

SEC. 3. At all business meetings of the Institute the presence of twenty-five Members and (or) Associates shall constitute a quorum.

SEC. 4. At all business meetings of the Institute, Members and Associates entitled to vote may vote only in person. Any matter which is presented over the signatures of twenty-five Members or Associates, or which is advocated or opposed by twenty-five Members or Associates present at a business meeting of the Institute, or which the Board of Directors may wish to refer to the membership for decision, shall be sent out to the membership for a vote thereon by letter ballot, accompanied by a statement prepared by the Board of Directors giving the arguments for and against its adoption. Only Members and Associates entitled to vote may vote thereon.

SEC. 5. All meetings of the Institute other than business meetings shall be held at such times and places as the Board may appoint. Notice of all such meetings shall be given to all Members, Associates, and Junior Members by mail.

ARTICLE V.

DIRECTORS AND OFFICERS.

SEC. 1. The business, financial, professional, technical, scientific and social interests of the Institute shall be managed by and under a Board of Directors, elected annually by letter ballot in the manner specified in this Constitution or in the By-Laws, to serve for the terms set forth in the Certificate of Incorporation.

SEC. 2. The Board of Directors shall consist of a President, two Past Presidents, six Vice-Presidents, and fifteen Directors.

Eight Directors shall be elected annually by letter ballot: One of said eight shall be designated as "Director and President" and two shall be designated as "Director and Vice-President."

SEC. 3. The officers of the corporation, who shall also be termed the respective officers of the Institute, shall be a President, First Vice-President, Secretary, and Treasurer. The President shall be that Director who is chosen at the annual election as "President." He shall serve as President for one year, and for the subsequent two years of his directorate be termed "Past President of the Institute." The President shall be ineligible for re-election as such until two years after expiration of his term as President.

At the first meeting of the Board of Directors after the annual business meeting of the Institute, the Board shall elect a First Vice-President, to hold office for one year, from among the Vice-Presidents of the Board; a Secretary, who may or may not be a member of the Board, to serve for one year; and a Treasurer from among

the members of the Board, to hold office for one year. The Secretary or the Treasurer may be removed from office at any time by a unanimous vote of the Directors present at a special or regular meeting of the Board, due notice having been given in advance that such action is to be considered at said meeting. The Secretary shall receive such salary as may be fixed by the Board of Directors.

The duties of all officers shall be such as usually pertain to their respective offices, together with such other duties as may from time to time be prescribed for them by the By-Laws or Board of Directors. The Treasurer shall give a bond for the faithful performance of his duties, in a sum to be fixed by the Board of Directors, but at the expense of the Institute.

SEC. 4. In the event of a vacancy occurring in the Board of Directors by death, resignation, promotion by election as President or Vice-President, or for any other reason than retirement at the end of three years' service, the remaining members of the Board shall elect a successor to fill the vacancy and to serve for the unexpired term. A member of the Board whose term has not expired and who is elected President or Vice-President at an annual election shall be considered to have vacated the former office held by him, and the Board shall fill the vacancy as above provided.

SEC. 5. The Board of Directors may, from time to time, in its discretion, appoint any Past Secretary of the Institute "*Secretary Emeritus*," to receive such compensation and to perform such duties as the Board may designate.

SEC. 6. The Board of Directors may authorize the formation of Local Sections, Technical Committees, or arrange affiliations with other Societies in accordance with this Constitution and the By-Laws.

SEC. 7. The Board of Directors may appoint standing and special committees charged with such duties as the Board may assign. Such committees shall be directly responsible to, and report to the Board, and take only such responsibilities as the Board shall authorize.

SEC. 8. At the first meeting of the Board of Directors after the annual meeting of the Institute, it shall appoint an Executive Committee of five of its members, three of whom shall constitute a quorum. This committee may act for the Board between meetings of the Board and at any regular or special meeting whenever a quorum of six Directors is not present. The Executive Committee is not authorized to perform the following acts, or any others the Board may see fit to interdict, viz.: fill vacancies on the Board; elect the First Vice-President, Secretary, or Treasurer; fix salaries of officers (it may fix those of employees); vote extra compensation to officers; vote extraordinary expenses or incur obligations of over five hundred dollars; take action affecting already invested funds or property rights of the Institute; elect Honorary Members; expel Members.

SEC. 9. The Chairmen of Local Sections or appointed representatives thereof, and the chairmen of the Technical Committees or Divisions of the Institute, if not members of the Board of Directors, shall be notified of and have the privilege of attending all meetings of the Board, but without the right to vote. They may participate in discussion, and shall receive the minutes of the Board's meetings.

SEC. 10. All salaries paid by the Institute shall be fixed in advance by the Board of Directors, but no salary shall be fixed in advance for a period longer than twelve months.

SEC. 11. The funds of the Institute shall be paid out only by check signed by the Treasurer and countersigned by the Secretary; in case of absence or disability, the President or First Vice-President may act for the Treasurer, or any Vice-President for the Secretary.

SEC. 12. The Directors may appoint an Assistant Secretary, who shall, under the instructions of the Board, have charge of such of the business affairs of the Institute as may be assigned to him by the Board. His salary shall be fixed by the Board, and he shall hold office during its pleasure.

ARTICLE VI.

MEETINGS OF THE BOARD OF DIRECTORS.

SEC. 1. A regular meeting of the Board of Directors for the election of officers and the transaction of other business shall be held in February of each year, at the headquarters of the Institute, in New York City, after the annual business meeting of the Institute has adjourned.

SEC. 2. The Board of Directors shall also meet once each month except in July and August, on a regular date to be fixed at its February meeting, for the transaction of such business as may come before it.

A conference of the Board may be called at the request of three members of the Board, or by the President, to meet at any time or place, in connection with a meeting of the Institute for reading and discussion of papers or for the discussion of matters affecting the welfare of the Institute. All recommendations adopted by a majority of those present at such conference shall be transmitted to the Secretary of the Institute, accompanied by a record of the number favoring such recommendations, together with notes of the discussion thereon, and by him brought before the next meeting of the Board of Directors for consideration and such action as it may deem expedient.

Special meetings of the Board shall be called by the Secretary at the request of the President, First Vice-President, or any three members of the Board, to meet at any time and place, by notice mailed to the members of the Board at least ten days in advance, or by telegram sent at least five days in advance of the date of the meeting to members in North America (Alaska excepted).

SEC. 3. At all meetings of the Board of Directors the presence of six members shall constitute a quorum. In the absence of said quorum at any meeting of the Board, a quorum of the Executive Committee, if present, shall transact such necessary business as is within the powers delegated to that Committee.

ARTICLE VII.

NOMINATION AND ELECTION OF DIRECTORS AND OFFICERS.

SEC. 1. A ticket of nomination for offices and places annually falling vacant in the Board of Directors shall be prepared by a Committee on Nominations, of which no member shall be, at the time, on the Board. This Committee shall consist of the Chairmen of three Local Sections, one ex-President, and three other Members of the Institute, and, on recommendations made by the President of the Institute, shall be appointed by a vote of the Board of Directors, within ninety days after the annual meeting, and it shall then proceed to the selection of candidates and the naming of a ticket. In making such selections, the nominating committee shall, so far as practicable, distribute the representation on the Board geographically, so that seven members shall be residents of the district including New York City and the territory within a radius of fifty miles of the headquarters of the Institute, and one member a resident of each of the geographical districts enumerated in the By-Laws.

The official ticket thus formulated shall be transmitted to the Secretary of the Institute, not later than the last Friday in October, be submitted to the Board at

its October meeting for its consideration, published in the November *Bulletin*, and not later than January 1 be printed and sent to the membership. Any complete or partial ticket of nominees signed by any twenty-five Members or Associates of the Institute and transmitted to the Secretary by December 15 shall also be printed and circulated with the official ticket and over the names and with the recommendations of the nominators, together with an expression of opinion of the Board thereon if deemed expedient.

SEC. 2. The election ballots mailed with the nominations shall contain space for the naming of eight Directors, of which the first shall be designated: "For Director and President," the second and third: "For Director and Vice-President," and the rest: "For Director." They shall be accompanied by small inside adhesive envelopes marked: "Ballot. Do not sign," and outer mailing envelopes addressed to the Secretary and marked "Enclosing Ballots only." Members voting shall not sign their names to the ballot, but seal it in the inner envelope, enclose it in the outer mailing envelope, and write their names on the outside, in the place provided. Cumulative voting shall not be permitted. Letter ballots must reach the Secretary on or before the second Tuesday in February. He shall give them unopened to tellers, to be appointed by the Board of Directors at its January meeting, at least three days before the annual business meeting, marking plainly those from Members not entitled to vote, because of geographical location or by being one year or more in arrears for dues. The tellers shall open and count the valid ballots received from Members entitled to vote, rejecting any unidentified by the name of the sender on the outer envelope; they shall prepare a report of the voting and hand it to the Chairman of the annual business meeting of the Institute. The latter shall declare elected to the respective offices the eligible persons receiving the highest number of votes. The ballots and unopened letters shall be returned to the Secretary at the annual business meeting; the latter shall preserve them one month, and then destroy the ballots which have been counted, and open and destroy the others.

SEC. 3. At the annual election in February, 1913, at which time the former Board of nine Directors, of whom three will on that day retire, is, under the amended Certificate of Incorporation, to be succeeded by a new Board of twenty-four Directors, the Institute shall elect by letter ballot in the manner hereinabove provided (save that nomination therefor shall have been made by a committee appointed for that purpose by the Board of Directors prior to December 15, 1912), the following new Directors:

One President and Director, who shall serve as President for one year and as Past President for two years; two Past Presidents to be selected from former Presidents of the Institute, one to serve for one year and one to serve for two years; six Vice-Presidents, of whom two shall be elected to serve for one year, two for two years, and two for three years; and nine Directors, of whom two shall be elected to serve for one year, two for two years, and five for three years.

ARTICLE VIII.

PAPERS AND PUBLICATIONS.

SEC. 1. The Board of Directors shall appoint a Committee on Papers and Publications, of which the Secretary shall be a member, whose duty shall be to pass upon the fitness of technical communications submitted for publication by the Institute. Stenographic or contributed discussions of papers may be passed upon by the Secretary, in consultation with members of the above committee.

SEC. 2. The Institute shall not assume responsibilities for any statements of fact or opinion advanced in the papers or discussions at its meetings. Neither the Board nor the Institute shall officially approve or disapprove any technical or scientific opinion, or of any proposed enterprise which is outside of the management of the meetings, discussions and publications of the Institute, and the conduct of its business affairs by the Board of Directors.

SEC. 3. Special committees may from time to time be appointed by the Board to make investigations and prepare reports for presentation to the Institute, but no action shall be taken binding the Institute for or against the conclusions embodied in any such reports.

ARTICLE IX.

SUSPENSIONS AND EXPULSIONS.

SEC. 1. Any member of the Institute who shall be convicted of a crime involving, in the opinion of the Board of Directors, moral turpitude, shall, upon the passage by the Board of Directors of a resolution declaring the crime for which he has been convicted to be of such character, be thereupon dropped from membership in this Institute.

SEC. 2. Any Member of the Institute may be suspended or expelled for misconduct by the Board of Directors, after charges setting forth such misconduct shall have been prepared and filed in writing with the Board. Upon the receipt of such charges in writing, the Board may, in its discretion, suspend such Member pending a hearing and determination thereupon. As soon as may be after the receipt of such charges, the Board shall fix a date for a hearing thereupon and shall give to the accused Member notice thereof in writing, mailed to him at his last known post office address not less than thirty days before said date, accompanied by a copy of the charges and a copy of the second, third and fourth sections of this article.

SEC. 3. Upon the day fixed for the hearing, the accused Member may appear before the Board, either in person or by an accredited representative; hear any witnesses who may be called in support of the charges and, at his option, cross-examine the same, and hear read any documentary evidence offered in support of the charges. The accused may, in his discretion, produce and examine witnesses in his defense, and submit documentary evidence, including a statement from himself in writing. After the conclusion of the hearing, the Board of Directors shall consider and vote to approve or disapprove the charges. If the Board shall, by a vote of two-thirds of its members, declare the charges sustained, it may suspend the Member for a stated period, or expel him.

SEC. 4. If the accused Member shall not appear at the hearing, and shall within three months thereafter file with the Board an affidavit stating that he had not received notice of the charges against him in time to enable him to present his defense, the Board shall fix a date for a re-hearing within three months from the receipt of such affidavit, and shall immediately notify the accused Member by mail of such date. Upon the re-hearing, the accused shall have the same privilege of presenting his defense as he would have had upon the original hearing; and after the defense is presented, the Board shall take a new vote upon the charges, the result of which shall be conclusive.

ARTICLE X.

AMENDMENTS.

SEC. 1. Proposals to amend this Constitution shall be presented in writing to the Board of Directors, signed by at least ten Members ; they shall reach the Secretary not later than October fifteenth. The Board of Directors shall consider them and the proposers shall be notified of the opinion of the Board in regard to them, and they may then either withdraw their proposals, or accept any changes suggested, or insist on the original form. The original form, if insisted upon, together with the changes proposed by the Board, if such there be, shall be mailed to all Members on or before January first, with the election ballots, and with a ballot in proper form for voting upon the amendment in its original or amended form. Ballots shall be received by the Secretary until the second Tuesday in February. The Tellers of the election shall count these ballots, and report the result to the Chairman of the annual meeting. Any members present in person at the annual meeting who have not voted on the amendments by ballot, shall have the privilege of having their votes recorded before the result of the voting is announced. Any proposed amendment which shall have been accepted by a majority of the votes thus cast, shall be adopted.

BY-LAWS.

I. PRESIDING OFFICER.

At all business meetings of the Institute the President, or, in his absence, the first Vice-President, or, in the absence of both of them, any other Vice-President or Director, chosen by the meeting, shall preside.

At all other meetings of the Institute the President, or, in his absence, one of the Vice-Presidents, shall preside. If none of these be present the meeting shall elect a Chairman.

II. ORDER OF BUSINESS.

At each business meeting of the Institute the order of business shall be as follows :

1. Reading of minutes of preceding meeting.
2. Report of the President.
3. Report of the Treasurer.
4. Report of the Secretary.
5. Election of Directors.
6. Reports of Standing Committees.
7. Reports of Special Committees.
8. Special Orders.
9. Miscellaneous business.

This order of business may be changed at any meeting, by a vote of a majority of the Members and Associates present.

At all sessions of the Institute, other than business meetings, the order of proceedings and the time of adjournment shall rest in the discretion of the presiding officer.

III. SECRETARY OF THE INSTITUTE.

The Secretary shall keep a record of the proceedings of all meetings of the Institute. He shall be custodian of the corporate seal, of the minute books, and of all legal documents belonging to the Institute. He shall have charge, on behalf of the Institute, of all correspondence except such as pertains directly to the office of the Treasurer.

He shall notify all Officers and Directors and all members of committees of their election and appointment; shall issue notices of all meetings of the Board, and of the annual and other business meetings of the Institute; and shall, in calling special meetings of the Directors, specify the objects of such meetings. He shall act as clerk at all the meetings of the Board of Directors and at all meetings of the Institute.

The Secretary shall be custodian of all technical or scientific papers submitted to the Institute for its consideration, shall have general charge and supervision of the editing and proof-reading of all material published by the Institute, and of the distribution thereof, and be *ex officio* Chairman of the Committee on Publications.

On the first day of May following the year in which each volume of *Transac-*

tions is printed, he shall turn over to the Library Committee all copies of the same not theretofore distributed by him.

The Secretary may, with the approval of the Board of Directors, employ such persons as are necessary to constitute a clerical and office force, at such salaries as shall be approved by the Board of Directors or its Executive Committee. He shall be the immediate superior of all such employees.

IV. ASSISTANT SECRETARY.

The Board of Directors may, upon request of the Secretary, appoint an Assistant Secretary, to take charge of such portion of the Secretary's duties as may be assigned him by the Board or its Executive Committee, such as supervising the printing and distribution of advance papers, of the *Bulletin* and *Transactions*, soliciting advertising and conducting general business correspondence.

During the absence of the Secretary at meetings of the Institute, or for other reasons, he shall act as Secretary *pro tem*.

V. TREASURER.

The Treasurer shall collect and, under the direction of the Board of Directors, shall disburse all funds of the Institute. He shall keep regular accounts in books belonging to the Institute, which shall be open to any member of the Board of Directors. He shall report in writing at each annual meeting of the Institute, and at every regular meeting of the Board of Directors, the balance of money on hand, and any existing appropriations which may affect the same.

His accounts shall be audited annually by a committee of three Members or Associates to be appointed by the President at least thirty days prior to the annual meeting in each year, which committee shall report thereon at such annual meeting. The committee may employ a public accountant to assist it, at the expense of the Institute.

The Treasurer may, at his discretion, place funds of the Institute, not at any time exceeding five hundred dollars, in the hands of the Secretary, Assistant Secretary or Assistant Treasurer, and may delegate to either of them the duty of paying, therefrom, the smaller current expenses of the Institute. The Treasurer shall examine this "Cash Box" account each month.

The Treasurer shall be solely responsible to the Institute for all moneys received, whether the same are entrusted to others or not, and may require from any one to whom he entrusts funds, a bond, running to the Treasurer personally and taken at the expense of the Institute.

VI. ASSISTANT TREASURER.

The Board of Directors may appoint an Assistant Treasurer, to whom it may delegate the duties of conducting, under the supervision of the Treasurer, correspondence incidental to the office of Treasurer, of collecting, receiving and depositing in bank, to the credit of the Institute, all moneys, and of paying, out of a special account, if entrusted to him, the smaller current expenses of the Institute, subject to the instructions of the Treasurer. He shall hold no other office.

VII. STANDING COMMITTEES.

The standing committees of the Institute shall be four: A Finance Committee, a Library Committee, a Committee on Publications, and a Committee on Membership.

The Finance Committee shall consist of three members of the Board of Directors, who shall be appointed by the Board at its first meeting after the annual meeting of the Institute in each year.

The Library Committee shall consist of the Secretary of the Institute and four other Members or Associates of the Institute, one being appointed annually by the President, at the first meeting of the Board after the annual business meeting of the Institute, to serve for four years, in conformity with the By-Laws of the United Engineering Society, approved by the Board of Directors of the Institute.

The Committee on Publications shall consist of the Secretary of the Institute, who shall be its chairman, and at least twelve specialists, Members of the Institute, to assist in passing on all papers offered for publication. They shall be appointed annually by the newly-elected President.

The Committee on Membership shall consist of five Members of the Institute, the Chairman and at least one other member being chosen from the Board of Directors, and shall be appointed by the President at the first meeting of the Board after the annual business meeting of the Institute.

VIII. FINANCE COMMITTEE.

It shall be the duty of the Finance Committee to inquire into and examine the financial condition of the Institute and to consider proper means of increasing its revenues and of limiting its expenses. It shall report at each monthly meeting of the Board, and at other times whenever it shall desire or be directed so to do; and the Treasurer shall at all times furnish it with such statements and information as it may desire.

It shall determine, with the approval of the Board, the investment of such surplus moneys as shall from time to time accrue to the Institute. It shall, at least once in each year, examine the securities belonging to the Institute, and report thereon to the Board.

It may, at any time, examine the books and vouchers of the Treasurer and Assistant Treasurer.

The Treasurer shall not be a member of the Finance Committee, but shall attend the meetings of the same if requested.

The Finance Committee shall present a budget to the Directors at the meeting preceding the annual meeting of the Institute. This budget shall give an itemized estimate of the receipts and expenses of the Institute for the ensuing year. The Directors shall pass on this budget at their first meeting after the annual business meeting of the Institute, modifying it as they consider necessary, and make definite, detailed appropriations for the following year.

All bills, accounts, salaries, pay-rolls and claims of every kind against the Institute shall, before being paid, be examined by the Finance Committee and be approved by at least one member of the Committee. The Committee shall not authorize any payments in excess of appropriations. If at any time any of the appropriations seems in danger of being insufficient the Finance Committee shall report the same to the Directors.

IX. LIBRARY COMMITTEE.

The Library Committee shall constitute the official representatives of the Institute upon the Library Board of the United Engineering Society, and be guided by the By-Laws of that Society, as approved by the Board of Directors of this Institute, with full powers to act for the Institute within the appropriations allowed by the Board of Directors.

The Library Committee shall be the custodian of all books in the Institute library and of additions thereto ; also of all back numbers of the *Transactions* of the Institute. It shall, on the first day of May of each year, receive from the Secretary and receipt for all the volumes of *Transactions* and *Bulletins* or other publications for the preceding year not previously distributed by said Secretary.

It shall cause to be kept, under the directions of the Secretary, a catalogue of all books in the library and an account in ledger form of all volumes of *Transactions* in its custody, in which shall be charged all volumes delivered to it, and in which shall be credited all volumes taken from its custody for sale or for any other purpose.

It shall make a written report annually to the Board of Directors, stating the stock of publications on hand, and a detailed statement of sales during the year, together with such observations and recommendations as it may wish, regarding said publications or the conduct of the library.

X. COMMITTEE ON PUBLICATIONS.

1. This Committee shall perform its functions as follows :

(a) On the receipt of a paper by the Secretary (Chairman), he shall send it to the member of this Committee who, in his judgment, is most competent and available to pass upon it, as "Reader," accompanying the paper with his own opinion of its suitability for publication, and any other pertinent information.

(b) If the Reader and the Chairman agree upon the suitability or unsuitability of the paper, it shall be considered accepted for publication or rejected, as the case may be.

(c) If these two do not agree, the paper shall be submitted to a third member of the committee, and the opinion of two of these three members shall decide the matter.

(d) If a paper has been refused publication, the author shall have the right of appeal, in which case the persons previously passing on the paper, together with others selected from the Committee by the President—making five altogether—shall decide the question.

(e) If a paper has been accepted for publication, it shall be considered eligible to be placed on the program of a meeting.

2. The placing of a paper upon the program of a meeting shall not give it the right to be published in the *Bulletin* or *Transactions* of the Institute ; its suitability for publication must in every case be passed upon by the Committee, as provided for in Section 1 of this Article.

3. In case the Secretary is unable to secure a decision as to the suitability or unsuitability of a paper for publication, as directed in Section 1, before the time of announcing the program of a meeting, he may at his own discretion place the paper upon the program of the meeting, or refuse it a place thereon.

XI. COMMITTEE ON MEMBERSHIP.

All nominations for Members, Associates, or Junior Members of the Institute shall be submitted to and passed upon by the Committee on Membership. This Committee shall meet at least once in each calendar month, with the exception of the months of July and August. It shall receive and consider all communications respecting candidates, and shall make diligent inquiry as to the character and qualification of each. Its proceedings shall be reported to the Board, if required, but otherwise shall be secret and confidential.

No member of the committee shall propose any candidate.

XII. ELECTION OF MEMBERS.

After the Committee on Membership shall have reported to the Board its conclusions as to the acceptability of each candidate, the Board shall vote upon the same. No person shall be proposed for election to the Institute within one year after his name shall have been rejected by the Board.

XIII. NOMINATIONS.

The geographical districts to be considered by the Committee on Nominations shall be as follows, until otherwise ordered by the Board.

District No. 1. New England, New York, and New Jersey, excepting New York City and district, which is provided for in the Constitution.

District No. 2. Pennsylvania.

District No. 3. Ohio, Indiana, Illinois, Iowa, and Missouri.

District No. 4. Minnesota, Wisconsin, and Michigan.

District No. 5. Montana, North and South Dakota, Wyoming, Nebraska, Kansas, Washington, Oregon, Idaho, and Alaska.

District No. 6. California and Nevada.

District No. 7. Utah, Colorado, Arizona, and New Mexico.

District No. 8. Louisiana and Texas.

District No. 9. Other Southern States and District of Columbia.

District No. 10. Mexico.

District No. 11. Canada.

XIV. UNITED ENGINEERING SOCIETY.

This Institute shall be represented upon the Board of Trustees of the United Engineering Society by three Members or Associates, one retiring each year, as provided in the By-Laws of the said United Engineering Society.

At the December meeting of the Board of Directors the Board shall designate a Member or Associate of this Institute to be a representative of this Institute upon the Board of Trustees of the said United Engineering Society for a period of three years beginning at the next ensuing annual meeting of said Society.

At any time when a vacancy shall occur in the representation of this Institute on the Board of Trustees of said Society, the Board of Directors of this Institute shall designate a Member or Associate to fill such unexpired term.

These representatives shall report in writing to the Board of Directors at its regular meetings held in March, June, September, and December, and at any other meeting, if called upon by the Board.

XV. PUBLICATION OF A BULLETIN.

The publications of the Institute shall include, in addition to the *Transactions*, a periodical called the *Bulletin* of the American Institute of Mining Engineers which shall contain reports of proceedings, professional papers, notices and other matter of interest to Members. From the annual dues paid by each Member, Associate, and Junior Member, five dollars shall be deducted and applied as a subscription to the *Bulletin* for the year covered by such payment. Special volumes upon technical subjects may be issued, by vote of the Board.

XVI. OBLIGATIONS TO MEMBERS.

Any Member of whatever class whose dues are paid within the limits set by the Constitution shall receive the *Bulletin*; and all Members and Associates who pay

ten dollars annual dues, also all Life and Honorary Members, shall receive in addition the *Transactions*.

XVII. DIVISIONS.

SEC. 1. Professional groups to be known as Divisions of the Institute and to be organized from its members, may be authorized by the Board of Directors. Any Member of the Institute may register for membership in any Division in which he is interested and may resign therefrom provided he be under no financial obligation thereto.

SEC. 2. The officers of the Division shall be a Chairman, one or more Vice-Chairmen, a Secretary-Treasurer, and an Executive Committee. The Chairman, Vice-Chairman, and Secretary shall be *ex officio* members of the Executive Committee of the Division. All officers of Divisions shall be elected annually by letter ballot by the members of the Divisions, and shall take office at the close of the meeting at which they are elected. They shall hold office for one year or until their successors are elected.

SEC. 3. A Division shall have the right to make rules for its own government, subject to the approval of the Board of Directors, not inconsistent with the Constitution and By-Laws of the Institute. The Board of Directors shall have the right to amend, annul, or add to these rules.

SEC. 4. Any Division may raise or collect funds to be expended for its own purposes and may have the entire management and control of such funds in so far as said management or control does not conflict with the provisions of the Constitution and By-Laws of the Institute.

SEC. 5. The Board of Directors shall have the right to recommend the dissolution of any Division subject to approval of such recommendation at any annual meeting of the Institute, in which case the net property of such Division shall be divided pro rata among all members thereof in good standing.

SEC. 6. Each Division shall furnish the Board of Directors on the 1st of February in each year an annual financial statement of its affairs in such form as the Board of Directors may require.

XVIII. LOCAL SECTIONS.

SEC. 1. A Local Section of the Institute may be authorized by the Board at the written request of ten Members residing within an appropriate distance of a central point.

SEC. 2. The Board shall define the territory of a Section.

SEC. 3. Only one Section shall be authorized in one locality or district.

SEC. 4. A section must consist of at least twenty-five members; if its membership falls below twenty-five in number, the Board may annul the Section.

SEC. 5. Only Members and Associates of the Institute shall be members of its Local Sections.

SEC. 6. All Members and Associates of the Institute residing within the territory of a Section shall be eligible for membership in such Section. But any such person failing within three months, after due invitation, to become a member of such Local Section, shall thereafter be admitted to its membership and privileges only on such conditions as said Local Section shall determine.

SEC. 7. The officers of a Section shall be elected, after the formation of the Section has been duly authorized, at a meeting of the members of the Institute within the territory of said Section, called by the sponsors of the Section, notice of said meeting and its objects being given to said Members at least thirty days in advance. Officers of Local Sections shall be elected for a term not longer than one year.

SEC. 8. The Officers of a Local Section shall be a Chairman, Vice-Chairman, Secretary, Treasurer (or Secretary-Treasurer), and such others as the Section may desire.

SEC. 9. It shall be the policy of the Board of Directors of the Institute to contribute from its funds for the necessary running expenses of each Local Section, when and so far as practicable, an amount not exceeding, in each year, twenty-five per cent. of the dues received from the members of said Section in said year, but in no case exceeding the sum of two hundred and fifty dollars. Requests for such appropriation shall be signed by the Chairman, Secretary and Treasurer of the Section.

SEC. 10. If the expenses of a Section exceed the appropriation made by the Board, the difference may be made up by voluntary contributions from the members of said Section, if it shall so determine. The Institute shall not be responsible for the debts of any Section.

SEC. 11. The Board reserves the right to cancel a Section, or readjust its territory.

SEC. 12. Papers presented at Local Sections, and discussions thereon if reported, shall be the property of the Institute. They shall be submitted to the Publication Committee and published in the *Bulletin* or *Transactions* or both, if approved. Such papers shall not be published elsewhere *in extenso* without permission of the Board. The reading of a paper before a Local Section shall not carry with it the right of publication in the *Bulletin* or *Transactions* of the Institute.

SEC. 13. Neither the author of a paper presented to a Local Section nor the Local Section shall have the right to reprint a paper or publish it in advance of the meeting without obtaining the permission of the Publication Committee of the Institute, which may refuse, or determine the details of such permission. Nothing herein shall forbid the abstracting of a paper by the press after its presentation before a Local Section.

SEC. 14. The Institute shall print advance copies of papers offered to Local Sections, in order to facilitate discussion thereon, provided that such papers are approved for such advance publication by the Chairman or Secretary of the Local Section and by the Publication Committee of the Institute.

SEC. 15. Papers read before a Local Section may also be offered for reading or discussion at general meetings of the Institute, and shall be given equal standing with the other papers on the program of said meeting, when approved by the Publication Committee.

SEC. 16. Each Local Section shall transmit promptly to the Secretary of the Institute announcements of its proposed meetings and an abstract of its proceedings, including the names of authors and titles of all papers read before it, for the purpose of preparing a report thereon to be published in the *Bulletin* of the Institute, and for the purpose of enabling the Board of Directors to comply with sections 17 and 18 of these regulations.

SEC. 17. The By-Laws and regulations of Local Sections shall be subject to the approval of the Board of Directors.

SEC. 18. No action shall be taken by a Section which shall contravene the Constitution and By-Laws of this Institute.

XIX. TECHNICAL COMMITTEES.

SEC. 1. A Committee on Iron and Steel, in charge of the interests of the Institute in this branch of its activities, is hereby established.

SEC. 2. Other Technical Committees may be authorized by the Board of Direc-

tors, charged with the consideration of such topic or topics as the Board may assign, and having the duty of providing papers and discussions upon such topics for the meetings of the Institute.

SEC. 3. The Board of Directors shall designate the officers thereof, who shall hold office for one year or until their successors are appointed.

SEC. 4. The officers of a Technical Committee shall be a Chairman, a Vice-Chairman, and a Secretary.

SEC. 5. The Committee may adopt such rules as are necessary for the convenient conduct of its affairs, subject to the approval of the Board of Directors, or its Executive Committee.

XX. AFFILIATION OR CONSOLIDATION WITH OTHER SOCIETIES.

The Board of Directors may arrange conditions for the affiliation or consolidation with the Institute of any regularly organized group of engineers or any engineering society, whether heretofore or hereafter incorporated or otherwise, which by Constitution, By-Laws, and practice is in accord with the aims of this Institute.

XXI. AFFILIATED STUDENT SOCIETIES.

SEC. 1. Any society of undergraduates at a technical school, comprising students in any branch of engineering, metallurgy, chemistry, geology, etc., may be recognized by the Board, in its discretion, as an Affiliated Student Society, and its name, together with the names of its President and its Secretary, may be published in the *Bulletin* or the Year Book of the Institute. The individual members of such a society will not be catalogued as individual Members of the Institute, but may at any time be proposed for election as Junior Members of the Institute, in the usual way, and receive the *Bulletin* of the Institute, when elected, upon payment of five dollars annual dues.

SEC. 2. Technical papers presented before any such society, and recommended by the officers thereof, will be received and considered by the Publication Committee as if offered by Members of the Institute, and, if accepted, will be published, with the names of their authors, and with due acknowledgment to the said Affiliated Student Society. The members of such societies shall be welcome to use the facilities of the office and library of the Institute.

SEC. 3. Upon the request of the Secretary or other designated officer of any such society, accompanied with the necessary remittance, not more than three copies of the *Bulletin* for one year shall be sent postpaid to him at the reduced price given to public libraries. One volume of *Transactions* may be similarly furnished, at the price charged to Members of the Institute for extra copies.

SEC. 4. The conditions and details of this relation between the Institute and Affiliated Student Societies may be changed at any time in the discretion of the Board of Directors of the Institute; and the relation itself may be terminated at any time by the action of either party.

XXII. AMENDMENTS.

SEC. 1. Amendments to these By-Laws may be made by vote of a majority of the Directors, provided the amendments have been proposed by a member of the Board at a previous meeting of the Board and copies of the same sent to all members of the Board at least 20 days before the meeting at which they are to be voted on, and an expression of opinion invited thereon. At a later meeting they may be amended in form, but not in substance.

SEC. 2. Any Member or Associate of the Institute in good standing may propose amendments or additions to these By-Laws by sending such in writing to the Secretary. The proposal shall be brought before the Board at its next meeting, and, if sponsored by any one member of the Board, shall pass through the course required in the previous section. If the proposal is not so sponsored, it shall be returned to the proposer.

SEC. 3. Amendments or additions to these By-Laws may be proposed by sending the same in writing to the Board of Directors so that they are received by them at least sixty days before a business meeting of the Institute, and providing they be endorsed by the signatures of at least twenty Members or Associates in good standing at the time.

It shall be the duty of the Board of Directors to have such proposals printed in the next succeeding issue of the *Bulletin*, and to provide proper facilities for a vote of the membership thereon by letter ballot before the said business meeting. If favored by a majority of the ballots cast, the amendments shall be reported at the said business meeting as adopted, and shall thereupon become effective.

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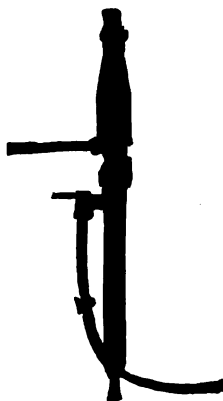
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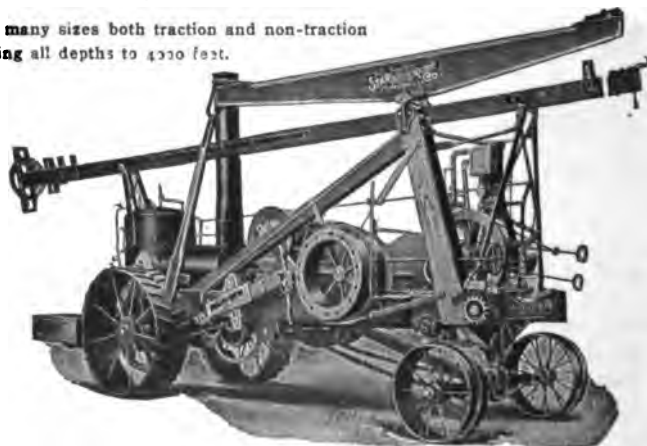
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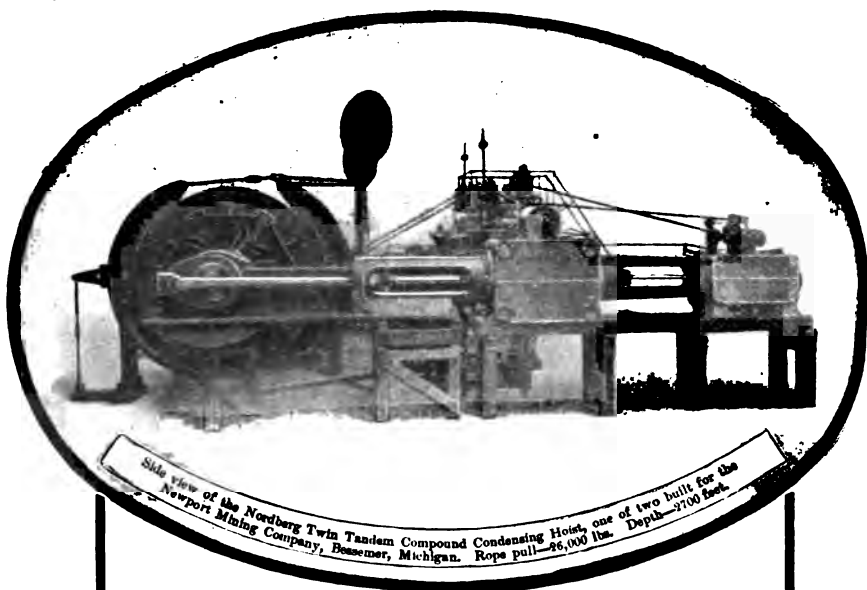
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